Massachusetts Institute of Technology

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1871-72.

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MASSACHUSETTS INSTITUTE

OF

TECHNOLOGY.

PRESIDENT'S REPORT.

To the Corporation of the Institute.

GENTLEMEN :—Your attention is respectfully invited to the accompanying reports, as carefully prepared statements of the condition of the departments to which they relate, and leaving but little to be said in addition.

Since the report of the department of Mining and Metallurgy was put in type, Mr. Samuel Bachelder, of Cambridge, has presentedto the Institute his very ingenious dynamometer, which accurately weighs all the power transmitted through it. This will enable the department to keep an exact record of all the power used in the mining and metallurgcial laboratory in running all or any of the machines in use. We have also received a Blake crusher, size 3″ by 5″, and a 12 inch Whelpley and Storer dry pulverizer. The new smelting and blast furnaces have been fully designed by Prof. Ordway, and their construction begun.

Our thanks are due to H. J. Booth & Co., of the Union Iron Works, San Francisco, California, for a very large and generous reduction in the price of the machinery furnished by them; and it is but justice to I. M. Scott, Esq., of that firm,

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who designed and built the five-stamp battery now in our laboratory, expressly for the Institute, to say that it is complete in all its parts, and gives entire satisfaction. Our thanks are also due to Col. J. J. Storer, for a large reduction in the price of his pulverizer.

Prof. Henck and a party of fifteen students in the department of Civil Engineering left Boston, on Thursday, the 6th of June, for the purpose of making a systematic study of the great railroad bridges over the Hudson, Ohio, Mississippi and Missouri rivers. On the way out each bridge will be examined by the whole party under Prof. Henck's direction, and a particular bridge assigned to each student, which he will be required to study in greater detail on his return; obtaining sketches and measurements of foundations and superstructure, and all the data for making a full report, accompanied with drawings of plan, elevation, sections, and all details necessary for the construction. We hope to do this summer for bridge construction, what was done the last for Mining Engineering and Metallurgy. It is proposed, hereafter, to make bridge construction a very important element in the course, and to this end it is earnestly recommended that models of all the important types of American bridges be supplied to the department as soon as possible.

We are well supplied with excellent field instruments, and the number is increased as fast as needed; but we have been, and still are, dependent upon the kindness of Prof. Peirce, Sup't. of the Coast Survey, for the use of a base-line measure, and a large altitude and azimuth instrument for triangulation, and for obtaining astronomical data for positions. It is most convenient for the department to use these instruments at the time when the subjects properly come in the course, and not when they can be best spared, if at all, by the Survey; and on this account it is very desirable that they be added to the collections of the department.

The work in the department of Drawing, both free-hand and mechanical, has upon the whole, been well maintained. Mr.

Schubert was absent last year for the purpose of study, and the break in the free-hand work, thus caused, has not been fully made up during the session just ended; but it is already evident that the department will be a great gainer in the end by the increased knowledge and appliances for instruction, which Mr. Schubert brought back as the fruit of his year's study in the celebrated art school of Nuremberg. The work in Descriptive Geometry and Stereotomy and the corresponding courses in Mechanical Drawing, will hereafter be under the same direction during the whole four years, which is expected to result in an improvement.

I am authorized by Hon. John Amory Lowell to announce that it is his intention to establish courses of instruction in the Institute in Designing as applied to the Industrial Arts.

These courses will be duly announced.

The Faculty of the School of the Institute has been increased during the past year by the appointment of Thomas Sterry Hunt as Professor of Geology, George H. Howison as Professor of Logic and the Philosophy of Science, and S. Edward Warren, as Professor of Descriptive Geometry, Stereotomy and Drawing. These gentlemen, eminent in their respective departments, will enter upon their duties with the new year.

At the recent entrance examinations, held June 3, and the following days, sixty-four applicants were admitted, sixty-two to the first year's class, and two to the second; an increase of thirteen over the corresponding examinations of last year. If the same proportional increase shall hold at the fall examinations the new class will largely exceed one hundred, and we shall be obliged to consider the question of a new building to meet the growing demands for space in which to properly carry on our work.

It gives me the greatest pleasure to be able to say that the most friendly and cordial relations continue to prevail between teachers and students, and that the past year's work in all departments has been of the most satisfactory character.

In accordance with your vote, the following brief sketch is appended for those who are interested in the origin and progress of the Institute in its several departments.

In the years 1858 and 59, an association of gentlemen residing in and near Boston, interested in the professional applications of science, and in the practical and fine arts, conceived the idea of securing the proper site on which to erect, in close proximity, such buildings as might be suitable and necessary for the purpose of the museums and collections of the Natural History Society, the Horticultural Society, and such others as might be formed representing the Industrial and Fine Arts, so as by their union and coöperation to constitute a comprehensive Museum, or Conservatory of Arts and Sciences.

With this view, after organizing as a "Committee of Associated Institutions," Hon. Marshall P. Wilder, Chairman, and Dr. Samuel Kneeland, Secretary, they petitioned the Legislature for a grant of land on the Back Bay, on which to erect buildings suitable for the proposed purposes.

At about the same time, Mr. William E. Baker had also suggested the desirableness of building up in some convenient location in Boston a Conservatory of Arts, and published some numbers of a Journal in advocacy and aid of the idea.

The time, however, seemed not yet to have come; the Legislature refused to make the grant of land, but the Committee, instead of being disheartened, redoubled their efforts.

About this time the matter was brought to the attention of Prof. William B. Rogers, whose deep interest in such subjects, and whose ability to aid in devising and consummating the proper plans to secure the desired ends, were well known. He prepared a memorial to the Legislature of 1860, which was adopted by the Committee. In this memorial we find the first suggestion of a School of Applied Science, in the plea for the early establishment of a "Comprehensive Polytechnic College," furnishing a "complete system of industrial education supplementary to the general training of the other institutions,

and fitted to equip its students with every scientific and technical principle applicable to the industrial pursuits of the age."

This, like the previous effort, failed to secure the favor of the Legislature, but it attracted attention to the growing importance of practical education, and led the way to the more definite scheme of organization which was developed in a Report by Prof. Rogers, and adopted by the Committee in the autumn of 1860. This Report, entitled "Objects and Plan of an Institute of Technology; including a Society of Arts, a Museum of Arts, and a School of Industrial Science," was read at a meeting of gentlemen interested in the establishment of an Institute of Technology, held at the rooms of the Board of Trade, October 5, 1860, and, on vote, was approved, and its publication recommended. The wide circulation of this able report, accompanied by an appeal to the public for coöperation and support, led to the calling of a meeting on Jan. 11, 1861, at Mercantile Hall, Summer St., "for the purpose of adopting measures preliminary to the organization of the Institute, and in furtherance of a petition to the Legislature for a charter, and a portion of the Back Bay lands."

The number of subscribers at this time amounted to 209.

The meeting was held at the appointed time; and after an exposition, by the Chairman, of the previous action and future purposes of the Committee, and interesting addresses by Prof. Peirce, Rev. Dr. Gannett, and others, in behalf of the Institute, a preliminary organization was established by adopting the following form of association, to which the names of those present were affixed: —

"We the subscribers, feeling a deep interest in promoting the Industrial Arts and Sciences as well as Practical Education heartily approve the objects and plan of an Institute of Technology, embracing a Society of Arts, a Museum of Arts, and a School of Industrial Science, as set forth in the Report of the Committee; and we hereby associate ourselves for the purpose of endeavoring to organize and establish in the city of Boston such an Institution, under the title of 'The Massachusetts Institute of Technology,' whensoever we may be legally empowered and properly prepared to carry these objects into effect."

The following resolutions were then adopted:—

"*Resolved*, That a Committee of twenty, with power to increase their number, be appointed to represent the interests and objects of the Association, and to act generally in its behalf, until it shall be legally incorporated and regularly organized under the title, and according to the purposes, of the Massachusetts Institute of Technology.

"*Resolved*, That said Committee be instructed to use its best efforts, in co-operation with the Committee of Associated Institutions of Science and Arts, to obtain from the Legislature an Act of Incorporation of the Institute, and secure a grant of land on the Back Bay for its use, and for that of other institutions devoted to the Practical Sciences.

"*Resolved, further*, That this Committee be requested to frame a Constitution and By-laws for the government of said Institute in its several departments, and to submit the same to the consideration of this Association, whensoever we may be in readiness, and properly empowered, to organize formally as the Institute of Technology."

Subsequently, on motion, the Chairman of the meeting was added to the Committee, to act as its Chairman.

The members of this Committee are as follows:—

W. B. ROGERS, *Chairman.*

J. M. BEEBE.	J. B. FRANCIS.
E. S. TOBEY.	J. C. HOADLEY.
S. H. GOOKIN.	M. P. WILDER.
E. B. BIGELOW.	C. L. FLINT.
M. D. ROSS.	THOS. RICE.
J. D. PHILBRICK.	JOHN CHASE.
F. H. STORER.	J. P. ROBINSON.
J. D. RUNKLE.	F. W. LINCOLN, Jun.
C. H. DALTON.	THOS. ASPINWALL.
E. C. CABOT.	J. A. DUPEE.

This Committee, in coöperation with the Committee of Associated Institutions of Science and Arts, again applied to the Legislature for a charter and land, which was granted in an act approved April 10, 1861. This act made "William B. Rogers [and others named] a body corporate, by the name of the Massachusetts Institute of Technology, for the purpose of instituting and maintaining a Society of Arts, a Museum of Arts, and a School of Industrial Science, and aiding generally, by suitable means, the advancement, development and practical application of science in connection with arts, agriculture, manufactures and commerce."

It also granted one square of land bounded on the east and west by Berkeley and Clarendon Streets, and on the north and

south by Newbury and Boylston Streets, the easterly one-third to the Boston Society of Natural History, and the remaining two-thirds to the Institute of Technology, with the condition that neither corporation should cover more than one-third of the land granted to it with buildings.

The Institute was formally organized under the charter, April 8th, 1862, by the election of William B. Rogers, President; John A. Lowell, Jacob Bigelow, Marshall P. Wilder and John Chase, Vice-Presidents; Thomas H. Webb, Secretary; Charles H. Dalton, Treasurer; and through the liberality of some gentlemen interested in the undertaking, sufficient funds were immediately raised to begin operations.

The first meeting of the Society of Arts was held December 17, 1862. Since that time it has continued to hold two meetings a month during the successive sessions; the 146th meeting having been held May 23, 1872. At these meetings are presented communications on various subjects of applied science, with the exhibition of machines and apparatus illustrating important inventions in the mechanic arts.

By an Act of the General Court of Massachusetts, approved April 27, 1863, the Institute receives from the State "one-third part of the annual interest or income which may be received from the fund created under, and by virtue of, the 130th chapter of the Acts of the 37th Congress, at the second session thereof, approved July 2, 1862. . . Said Institute of Technology, in addition to the objects set forth in its Act of incorporation, shall provide for instruction in military tactics."

A report by Prof. Rogers, on the "Scope and Plan of the School of Industrial Science of the Massachusetts Institute of Technology," was submitted to the Government by the Committee on the School of Industrial Science, and adopted May 30, 1864. This elaborate and carefully considered scheme forms the basis of the instruction in all departments, with only such changes and additions in the details of the organization and equipment of the laboratories as time and experience could alone determine.

The School was opened with temporary accommodations in Mercantile Library Building, Summer Street, in Feb., 1865, with a class of 27 students. The successive catalogues show the following summaries: 1865–6, 72; 1866–7, 137; 1867–8, 167; 1868–9, 172; 1869–70, 206; 1870–71, 224; 1871–72, 264.

Besides the systematic day courses the Institute proposed as a part of its work "to provide evening instruction for persons of either sex, who, being unable to study during the day desire to avail themselves of systematic evening lessons or lectures." Before this part of the school was opened, the following letter was received: —

BOSTON, *Oct. 26, 1865.*

DEAR SIR: —

I propose to institute evening courses of instruction, to be opened gratuitously to the public, under such regulations as may be deemed advisable.

It has occurred to me that these courses might with advantage be delivered in the first instance under the supervision of the Massachusetts Institute of Technology, and by their professors; the programme of course to be acceptable to me.

I shall devote to this purpose $3,000 a year, to be divided among the teachers in proportion to the time devoted by each.

If such an arrangement would be acceptable to the Government, I shall be happy to confer with you upon the subject.

Yours respectfully,

(Signed) JOHN AMORY LOWELL,
Trustee Lowell Fund.

PROF. W. B. ROGERS,
President Mass. Inst. Tech.

The proposal of Mr. Lowell was gratefully accepted by the Government, and this important department of the school has since continued to be conducted with the approval of Mr. Lowell, and at the expense of the Lowell Fund.

Among the largest benefactors have been William J. Walker, Ralph Huntington, James Hayward, and William Powell Mason, deceased, and Nathaniel Thayer and John Amory Lowell. The following statement will show the amount of cash gifts which the Institute has thus far received.

In 1862, $3,000; 1863, $175,610; 1864, $3,000; 1865, $132,761; 1866, $30,700; 1867, $58,000; 1868, $76,800; 1869, $4,000; 1870, $24,415; 1871, $63,500; 1872, thus far $3,300. Total, $575,086.

Respectfully submitted,

J. D. RUNKLE.

SECRETARY'S REPORT

FOR THE YEAR MAY 1871—MAY 1872.

In conformity with article 16, section 4, of the By-Laws of the Corporation, I herewith present the Annual Report of the Transactions and condition of the Institute for the tenth year 1871-1872.

There have been held during the year fourteen meetings of the Society of Arts. The meetings have been generally well attended, and communications have been made on the following subjects:—

Nov. 9, 1871. President Runkle gave an account of the Institute expedition to Colorado and Utah during the summer, for the observation of the mines and mining processes. The party consisted of five professors and fifteen students. The expedition was in every way a success, both in giving the students valuable information and in securing for the Institute a large supply of ores from many localities.

Nov. 23. Prof. Richards gave an account of an expedition to Wyoming and the Laramie Plains, illustrated by a series of ores from the mining regions of Missouri, Colorado, and Utah.

Mr. Wm. E. Hoyt gave a description of several European bridges of modern construction, illustrated by black-board drawings and a set of models belonging to the Department of Civil Engineering in the Institute.

Prof. Pickering explained the methods of teaching physical manipulation in the Physical Laboratory as regards the engineering course, and with special reference to bridges.

Prof. Watson exhibited a modification of the endless screw, by which the wheel is made the driver and the screw the follower — a very convenient form for obtaining considerable speed.

Dr. Samuel Gregg exhibited and explained a model of a system of ventilation, devised by himself, by which he claimed that a free ventilation can be obtained in cold weather without loss of heat.

Prof. Watson exhibited and described, by means of the calcium light, Prof. Faber's Speaking Machine, then on exhibition in Boston.

Dec. 24, 1871. The Secretary gave an account, from personal observation, of the way in which the bed of the Mississippi river, in the upper part of its course, is gradually filling up from the sediment carried in from newly cultivated fields in Minnesota and Wisconsin — and of the diminished rainfall from the destruction of forests — seriously interfering with the navigation of the river.

Prof. Cross made a communication upon the methods employed in illustrating the lectures on physics, by means of photographs projected on a screen.

The Secretary announced the donation to the Institute, by Thomas Gaffield, Esq., of two large and handsomely framed oil paintings, representing the manufacture of plate and of cylinder glass.

Dec. 28. Mr. Langley described a spliced joint for uniting rails — an automatic road-maker — and a working model of a machine for coiling wire to be used for inside support for rubber hose and for making all kinds of wire springs.

Mr. J. A. H. Ellis gave a description of his process of utilising the heat in exhaust steam to produce power in a second and connected boiler, by the use of bisulphide of carbon, a volatile liquid boiling at 110° Fahr., and at the temperature of exhaust steam giving a pressure of 65 lbs. to the inch.

Jan. 11, 1872. Dr. Sternberg, U. S. A., exhibited in operation and explained an electro-magnetic apparatus of his invention, the object of which is the automatic regulation of temperature, wherever artificial heat is employed and an equable temperature desirable.

Mr. James Hamblet, Jr., made a communication on electric clocks and the telegraphic distribution of time.

Jan. 25. Dr. Van Zandt, of California, exhibited in operation and explained an apparatus devised by himself for lighting and extinguishing street gas lamps by electricity.

Prof. Watson made a communication, illustrated by diagrams, on the ther engine. He also exhibited some models and drawings, the work of the students in the department of Stereotomy.

Feb. 8. Mr. E. H. Hewins read a communication, illustrated by the calcium light, on European and American bridges compared.

Prof. Watson made some observations on the history of ancient bridges.

Prof. Pickering exhibited specimens of so-called "mineral wool," made by blowing high-pressure steam through melted slag; this is well adapted for steam packings and similar purposes, being incombustible and a non-conductor of heat. He also showed a plate of glass on which an engraving had been cut by the sand blast; and called attention to various methods of photographic engraving, some of which promise to revolutionize the art of book illustrations.

Mr. J. F. H. Markoe exhibited an improved achromatic stereoscope, from London, adjustable for all kinds of focal distances, and for each eye separately.

Feb. 22. Prof. Watson read a paper, illustrated by diagrams and models, on the history, construction, and recent improvements of turbine water wheels, accompanied by an account of some recent experiments to test their efficiency.

Prof. Richards made a communication, illustrated by the apparatus, on Gifford's Injector as a substitute for Bunsen's filter pump.

March 14. Mr. S. Dana Hayes read a paper, illustrated by experiments and specimens, on the "History and Manufacture of Petroleum Products."

March 28. Mr. McMurtrie explained by the aid of diagrams on the blackboard, the Blanchard boiler — in which the water space is divided by horizontal diaphragms into three nearly separate compartments, communicating only by small openings. He compared this boiler with other horizontal tubular boilers in Portland, Me., — stating that on a competitive trial a great advantage is claimed for it on the point of economy in fuel.

Prof. Richards explained the mining machinery recently put up in the laboratory of the Institute; after which the Society adjourned to witness its operation.

April 11. Mr. Langley exhibited and described a new fusible plug, and showed it in operation on a boiler.

Mr. J. A. Grosvenor explained a new injector, also exhibited it in operation.

Mr. Libby, of Medford, Mass., exhibited a model of a diagonal turbine water wheel of his invention.

April 25. Prof. Watson made a communication on Compound Marine Engines, illustrated by a model of the Engines of the Cunard Steamer "Hecla."

May 9. Mr. E. C. Merrill explained a process, invented by himself, of making artificial stone, illustrated by an extensive suite of specimens. His materials are oxide and chloride of zinc, and carbonate of baryta.

May 23. Mr. N. M. Lowe exhibited and explained a new instrument for recording by electricity the force and direction of the wind, devised by himself, with valuable suggestions from Mr. H. E. Cole.

Prof. Pickering then described the changes introduced in the department of Physics during the past year.

To show the practical nature of the work done this term by the students of the graduating class, a number of specimens of their handiwork were next described. They included a model

of a suspension bridge, having a span of about eight feet, a Howe truss, and a queen-post truss, and the flexure under different loads carefully measured by them. A new method of measuring the torsion or twisting of a beam under different loads was shown, using mirrors attached to each end, and placing opposite to them telescopes by which the reflection of a graduated scale was observed. A very slight motion of the beam and mirror moved the image of the scale several inches, so that extreme accuracy was thus attainable. The apparatus was also shown by which they had measured the cofficients of efflux or flow of water through apertures of various sizes, also the resistance or friction of water in pipes. These quantities form the basis of the science of hydraulics.

A chronograph for measuring very small intervals of time, as a hundredth or even thousandth of a second, was also shown. In this instrument, which was entirely the work of another student, Mr. Guild, the time is measured by the vibrations of a tuning fork drawing a line on smoked glass.

As work of quite a different kind, a collection of photographs were exhibited, taken by different students as a part of their regular studies, among them several views of objects seen under the microscope and greatly magnified. Although the platform and tables were covered with apparatus like the above, yet much remained that was not exhibited for want of room, showing that the amount of work done by the class was extremely large.

Among the advantages claimed for this kind of instruction the following may be mentioned: First, it cultivates the powers both of the mind and hand, and gives a thorough practical familiarity with methods of experimenting, commonly attained only by long and laborious trials on the part of the student after graduating, when called upon to perform these experiments in connection with his daily duties. Again, much of this work is of considerable scientific merit, and with proper means results might be obtained not only of great scientific value, but of

equal value to the mechanical arts, especially all matters relating to heat, steam and motors. The large amount of work is in a great measure due to the interest felt in the matter by the students themselves, who often come into the laboratory late in the afternoon, or during the dinner hour; and, since it becomes a pleasure, it is sure to be done well. Finally, many of the experiments once prepared by an older student can afterwards be used by the younger ones, and thus they are like so many assistants, improving the course for their successors at the same time that they are instructing themselves.

There have been elected during the year 13 members of the Society of Arts, of whom 12 have consummated their membership. One life member has joined during the year, Mr. Allen; no corresponding or honorary members have been elected.

Prof. Daniel Treadwell, the only Honorary Member, has died during the year; Mr. Jacob A. Allen, of Lynn, has also died, one of the victims of the Revere disaster. Deducting 2 who have died, 21 who have resigned, and 10 who have been dropped for non-payment of fees, there are now on the list 345 members, of whom 65 are life members, exempt from assessment.

About 280 students have attended the school of Industrial Science during the year. Of these, two are graduates pursuing an extended or post graduate course. In the first year were 91 students, in the 2d 39, in the 3d 33, in the 4th 17; and 90, not candidates for a degree, following various special or partial courses, principally chemistry, drawing, and architecture. Thirty-one professors and teachers are connected with the school, and the fees from the students have been about $37.000.

The apparatus for instruction has been largely increased during the year. Full details on the various departments of the school have been presented by the professors in charge.

The Lowell courses this year have been given on the following subjects:

A course of ten lectures on English Writers of the 18th and 19th Centuries, by Prof. Atkinson, on Wednesdays, at 7½ P. M. beginning November 15, 1871.

A course of eighteen lectures on Progressive Development of Life in Geological Ages, by Prof. Kneeland, on Tuesdays and Fridays, at 7½ P. M., beginning November 14.

A course of eighteen lessons in Elementary German, by Instructor Krauss, on Mondays and Thursdays, at 7½ P. M., beginning November 13.

A course of eighteen lessons in Elementary French, by Instructor Levy, on Mondays and Thursdays, at 7½ P. M., beginning January 22, 1872.

A course of twenty lectures in Elementary Chemistry, by Professors Richards and Nichols, on Tuesdays and Fridays, at 6½ P. M. beginning January 16.

A course of twenty-four Laboratory Exercises in Chemical Manipulations, by Professors Richards and Nichols, on Wednesdays and Saturdays, at 2½ P. M., beginning February 3.

A course of twenty-four Laboratory Exercises in Physics, by Prof. Pickering, on Wednesdays and Saturdays, at 2½ P. M., beginning February 3.

These courses were well attended, the greater number of persons availing themselves of the last two courses being engaged in teaching.

At a meeting of the Corporation, held June 13, the following votes were passed:—

Voted, That the Corporation will hereafter confer the degree of Bachelor of Science in the department of——, instead of graduate of the Massachusetts Institute of Technology, in the department of——, as heretofore.

Voted, To establish advan[illegible]courses of study and to confer the degree of Doctor of Science, subject to the following conditions:

1. *Advanced Students.* Bachelors of Science in any department of the Institute may enter upon these courses without examination; but bachelors of arts, science, or philosophy, of any

other institution, must give satisfactory evidence, by examination or otherwise, that they are fully qualified to enter upon any proposed course of study.

Any person may enter upon an advanced course of study, and become a candidate for the degree of Doctor of Science, who, by examination, shall be found qualified to take the degree of Bachelor of Science in any department of the Institute.

2. *Advanced Courses.* The course of study which any student may wish to pursue must be presented in writing and approved by the Faculty. His proficiency in this course will be tested by frequent examinations. All departments will be open to him, but there will be no examination required in voluntary studies.

The methods of instruction, whether by lectures, or projects, or field or laboratory work, will be adapted to each particular case.

3. *Term of Residence.* The minimum term of residence will be two years, but the degree will not be given until the student shall have fully completed his chosen course.

Occasional short absences from the Institute, spent in professional work by the advice of the Faculty, will be counted as residence.

4. *Examinations.* Periodical examinations will be held to inform the student as to his progress; and the results of all such examinations, as well as of the semi-annual and degree examinations, will be taken into account in conferring the degree.

He must present at least one printed thesis upon some subject embraced in his course.

5. The fees will be $150 a year, and the cost of materials consumed in laboratory work.

6. There are five advanced scholarships of $150 each which will be awarded by the Corporation on recommendation of the Faculty. Applications must be made to Samuel Kneeland, the Secretary of the Institute, in writing, on before the first of October next.

SAMUEL KNEELAND, Secretary.

Massachusetts Institute of Technology.

REPORT OF THE DEPARTMENT OF GEOLOGY AND MINING ENGINEERING.

To the President of the Institute:—

The changes recently made in the department of Geology, Mining and Metallurgy, and the very considerable additions made to the means of instruction in these studies, more especially the establishment of a Mining and Metallurgical Laboratory, are sufficient reasons for calling the attention of the Corporation to the present condition of this department.

The regular course extends over four years, and the range of studies pursued is indicated by the following scheme of instruction.

First and Second Years.

Mathematics. Algebra. Solid Geometry. Mensuration. Plane Trigonometry and Spherical Trigonometry. Analytic Geometry. Elements of the Calculus.
Surveying. Field-work. Plotting Surveys. Computing Areas. Plans.
Physical and Industrial Geography.
Physics. Mechanics of solids, liquids and gases. Sound. Light. Heat. Magnetism. Electricity.
Chemistry. Qualitative Analysis. Chemistry, Organic and Inorganic.
French.
German.
English.
Descriptive Geometry.

Mechanical and Free-Hand Drawing.
Descriptive Astronomy.
Physiology and Hygiene.

Third Year.

Civil Engineering. Survey and Construction of Roads and Railways. Measurement of Earthwork and Masonry. Field Practice.
Mathematics. Differential and Integral Calculus. Analytic Mechanics.
Applied Mechanics. Stress. Stability. Strength and Stiffness.
Geology. General descriptive and theoretical Geology.
Zoology and Palæontology.
Mining. Ore-deposits. Prospecting. Boring. Sinking Shafts, etc. Methods of Mining.
Mineralogy. Descriptive and Determinative. Crystallography. Use of the Blowpipe.
Chemistry. Lectures and Laboratory Practice in Quantitative Analysis.
Assaying. Wet and dry ways.
Metallurgy. Metallurgical processes. Constructions and Implements.
Physics. Laboratory Practice.
English and Constitutional History.
French or Spanish.
German.
Drawing.

Fourth Year.

Mining. Ventilation. Winding-machinery. Underground-transport. Pumps. Dressing and Concentration of ores. Practice in Mining Laboratory in Ore-dressing.
Economic Geology. Detailed description of American ore-deposits and mines.
Strength of Materials and Hydraulics.
Machinery and Motors. Hand-machinery. Water-wheels. Boilers. Steam-engines.
Chemistry. Lectures, and Laboratory Practice. Synthetic Experiments. Quantitative Analysis.
Geology. American Geology; Lithological, Stratigraphical, Palæontological.
Chemical Geology. Origin of rocks, vein-stones, ore-deposits, coal, petroleum, salt, etc.
Metallurgy.
Practical Lithology and Building materials.
Physics.

Drawing. Geological Maps and Sections. Plans of Mines. Mining Machinery and Implements.
English Literature.
Political Economy.
French or Italian.
German.

The four years' course is so arranged as to secure to the student a liberal mental development and general culture, as well as the more strictly technical education which is his chief object.

The studies of the first and second years are somewhat general in character, but are regarded as a necessary foundation for the more special studies of the two succeeding years.

The special professional studies peculiar to this department commence with the third year.

Instruction is given by lectures and recitations, and by practical exercises in the field, the laboratories and the drawing-rooms. In most of the subjects problems are given the students, to be worked out outside of the lecture-room. A high value is set upon the educational effect of these practical exercises.

The space devoted to laboratories, and the prominence given to laboratory work, in Physics, Chemistry, Assaying, Blowpipe-analysis, Metallurgy and Ore-dressing is a marked feature in the scheme of instruction of the Institute. It is believed that this school offers unusual facilities in this regard.

The Chemical Laboratories cover 4,000 square feet.

The Mining, Metallurgical, and Assay Laboratories cover 2,000 square feet.

The Blowpipe Laboratory covers 550 square feet.

The Physical Laboratories cover 3,500 square feet.

The Drawing Rooms cover 8,556 square feet.

A course of thirty lectures on Physical Geology and Geography is given to the students of the second year by Professor Niles.

The study of the surface of the earth, of its external fea-

tures, their origin and modifications, is essentially the subject of this course. A proper knowledge of the surface includes necessarily a corresponding acquaintance with the arrangement of rock-masses, in so far as they have determined the character of the surface-features, and especially the geological agencies which are constantly producing the changes of the surface.

The aim of the instruction, in the course of Prof. Niles is, therefore, to present clearly the most important relations between surface features and underlying geological formations, and to show the action of the great dynamical forces; or in other words to teach Physical Geography and Physical Geology in their natural relations.

The knowledge of these relations becomes of great practical value in determining the extent or even probable occurrence of certain ore-bearing rocks, and of coal-beds in certain districts, since, where the rocks are completely covered by soil, the topographical features may be the only guide in "prospecting."

Exercises, Third and Fourth Years.

Descriptive and Theoretical Geology	30 lectures	Prof. Hunt.
American Geology	30 lectures	" "
Practical Lithology and Building Stones	15 lectures	" "
Chemical Geology	15 lectures	" "
Mining	70 lectures	Prof. Rockwell.
Economic Geology	20 lectures	" "
Palæontology	50 lectures	Prof. Hyatt.
Metallurgy	40 lectures	Prof. Ordway.
Industrial Chemistry	40 lectures	" "
Quantitative Analysis	40 lectures	Prof. Crafts.
Chemical Laboratory Practice.	10 to 15 hours a week	" "
Assaying, dry way	10 ex. (2½ hrs. each)	Prof. Richards.
Blowpipe and Determinate Mineralogy	45 ex. (1 to 2 hrs. each)	" "
Descriptive Mineralogy	15 lectures	" "
Mining and Metallurgical Laboratory Practice	10 hours a week	
Physical Laboratory Practice	3 hours a week, 1 year	Prof. Pickering.

Calculus	60 lessons	Pres. Runkle.
Mechanics	60 lessons	" "
Civil Engineering	40 lessons	Prof. Henck.
Strength of Materials and Hydraulics.	40 lessons	Prof. Watson.
Machinery and Motors	25 lessons	" "
Natural History	25 lectures	Prof. Kneeland.
French	2 hours a week	
German	2 hours a week	
English	2 hours a week	
Drawing	3 to 6 hours u week	

GEOLOGY, LITHOLOGY, ETC.

The instruction in Geology and certain related subjects is given by Prof. Sterry Hunt, in four courses, delivered year'y to students of the 3d and 4th years.

I. *3d Year.* The *first* is a yearly course of thirty lectures on *Descriptive and Theoretical Geology.* This embraces the classification of the Sciences; Scope of Geological Studies; Nature of Rocks, or Lithology; Stratigraphy; Succession of Formations; Zoological History; Geological Dynamics; Chemical and Physical Forces; Aqueous and Igneous Agencies; Currents; Sedimentation; Elevation and Subsidence; Geographical Distribution of Formations; Nature and Origin of Mountains; Volcanic Action.

II. *4th Year.* The *second* is a yearly course of thirty lectures on *American Geology*, comprising Introduction; Geological History; Geology of North America, considered (1) Lithologically; (2) Stratigraphically; (3) Palæontologically; Comparative Geognosy.

III. The *third* is a yearly course of fifteen lectures on *Practical Lithology*, comprising the mineralogical composition of Rocks; Building-stones, their cohesion, porosity, etc.; Granites, Marbles, Limestones, Sandstones, Slates; Limes, Cements, and Mortars; Ornamental Stones and Gems.

IV. The *fourth* is a yearly course of fifteen lectures on *Chemical Geology*, or the Chemical History of the Globe; comprising the Origin of Rocks, both stratified and unstrati-

fied; the History of Vein-stones and Ore-deposits; the Formation of Coal and Petroleum; the Chemistry of Salt-deposits and of Mineral Waters; the Seat and Origin of Volcanic and Earthquake phenomena.

MINING AND ECONOMIC GEOLOGY.

The instruction in Mining and in Economic Geology is given by Prof. Rockwell, in two yearly courses, delivered to students of the 3d and 4th years.

I. The *first* is a yearly course of 70 lectures on *Mining*. The student is made acquainted with the general character of the various deposits of the useful minerals, and with the theory and practice of mining-operations, such as the methods of search or "prospecting," — boring for oil, coal or water,—the sinking of shafts, with the timbering, walling or tubing of the same, the driving of levels; the different methods of working lodes, coal-beds, etc., the underground-transportation of the mineral, hoisting, pumping, ventilation and lighting, together with the machinery and other appliances connected with these and other operations; in short, the great variety of operations comprised under the general term, Exploitation. Ore-dressing, or the mechanical separation of ores from their gangues, is discussed somewhat at length, and the machines described by means of which this concentration is most economically effected. The practical course of ore-dressing and smelting in the Mining and Metallurgical Laboratory, affords the student opportunities for acquiring a familiar knowledge of the treatment of ores, such as can be got, under ordinary circumstances, only at the best mines.

II. The *second* is a yearly course of twenty lectures on *Economic Geology*, mainly devoted to a detailed description of the coal and ore-deposits of North America, especially such as are most extensively worked.

The student who is a candidate for the degree of the Institute, is expected to spend a portion of his vacations in some one

of the principal mining-districts in the study of the local peculiarities of the ore-deposits, and the details of actual working, and to submit a full report upon the same, with drawings. Those who intend to become metallurgists, may take smelting-works instead. Through the kindness of several proprietors certain mines in different regions have been made accessible to students, for the purpose of systematic study.

METALLURGY AND INDUSTRIAL CHEMISTRY.

The instruction in Metallurgy and in Industrial Chemistry is given by Prof. Ordway, in two courses of two years each, delivered to students of the 3d and 4th years.

I. The *first* is a two years' course of forty lectures on *Metallurgy*. The subjects discussed are fuels, fluxes, slags, furnace construction, and the roasting, smelting and refining of the various metals.

II. The *second* is a two years' course of forty lectures on *Industrial Chemistry*. The manufacture of acids, alkalies, salts, pottery, glass and organic products, and the arts of dyeing and printing are the principal subjects treated of.

In connection with these lectures, excursions are made to Manufactories and Metallurgical Works, and practical exercises are given in the laboratories. The students are required to make drawings and designs of apparatus used or to be used in large operations.

MINING AND METALLURGICAL LABORATORY.

The purpose of this laboratory is to furnish the means of studying experimentally the various processes of ore-dressing and smelting. Ores of all kinds are here subjected to precisely the same treatment, and by the same machinery and other appliances that are in use at the best Mines and Metallurgical Works of this and other countries.

The laboratory has already in successful operation the most approved Ore-dressing and Mill-machinery for gold and silver ores now in use in California and Nevada; consisting of a *five-stamp-battery*, an *amalgamating-pan*, a *separator* and a *concentrator*, complete in every respect, and capable of treating half a ton of ore a day. These were obtained the past summer in San Francisco. There will be added during the present year an ore-crusher, a hydraulic jigger, a Rittinger shaking-table, and all other appliances necessary for the treatment of every kind of ore. The machinery is driven by a steam-engine of upwards of 15 horse-power.

For Metallurgical treatment the laboratory contains at present a reverberatory roasting-furnace, crucible and assay-furnaces, and a blacksmith's forge; and there are now being erected reverberatory and blast smelting-furnaces capable of working 400 pounds of ore per day, and a cupelling-furnace sufficient for working 50 pounds of lead at once. To these will be added retort and other smaller furnaces for various uses. All of these will be ready for use by October of the present year.

The experimental work of this laboratory is carried on by the students, under the immediate supervision of Prof. Richards. A sufficiently large quantity of ore is assigned to each student, who first samples it, and determines its character and value by analysis and assays, and makes such other preliminary examinations as serve to indicate in a general way the proper method of treatment. He then treats the given quantity, makes a careful examination of the products at each step of the process, ascertains the amount of power, water, chemicals, fuel and labor expended. In this way the same ore is subjected to several methods of treatment, and by a comparison of the results obtained, the student learns the relative effectiveness and economy of different methods, as applied to the same ore. It is believed that the experiments conducted in this way, and upon such a scale, will prove of direct practical value, not only to the student, but to the Mining interest at large, by showing how existing methods of treatment may be advantageously modified to meet the requirements of new complex ores.

The Institute has now on hand about eleven tons of gold and silver ores, representing over seventy different mines in Colorado and Utah, which were collected by the Institute-party of professors and students during their recent trip to these territories. These ores will be worked, and reports of the results sent to those who so generously contributed them; and it is hoped that by such coöperation the laboratory will continue to receive the necessary amount and variety of ores.

The following experiments upon gold ores have been begun; but all the products have not yet been fully tested, on account of the approach of the annual examinations: —

1. The —— Lode, Nevada City, Colorado, 324 lbs.
2. The —— Lode, Nevada City, Colorado, 110 lbs.
3. The —— Lode, Central City, Colorado, 255 lbs.
4. The —— Lode, North Carolina, 103 lbs.
5. The —— Lode, Central City, Colorado, 250 lbs.

PALÆONTOLOGY.

The instruction in Palæontology is given in a yearly course of 50 lectures by Prof. Hyatt, one-half of which are delivered to the 3d year and one-half to the 4th year students.

Palæontology, or the history of ancient animal life, and Stratigraphical Palæontology, or the study of the distinctive and characteristic fossils of the different formations, are taught as a necessary foundation for the further study of Geology. The aim of the course is to give the student a practical acquaintance with the structure of the characteristic families, and orders of living and extinct animals, and by a judicious selection of examples to familiarize him to some extent with the genera which characterize various formations.

The handling and the drawing of specimens by the students is an essential feature of the method of instruction. The lectures of the instructor are devoted largely to explanatory demonstrations of the specimens which the students are at the same time drawing. The success attending this mode of teaching palæontology has shown its value.

MINERALOGY AND BLOWPIPE PRACTICE.

The instruction in Mineralogy and the use of the Blowpipe is given by Prof. Richards, in two courses to students of the 3d year.

I. The first is a course of 45 exercises (of one to two hours each), in which the student is taught Determinative Mineralogy by the study of crystalline forms, and the physical properties of minerals. He is instructed in the use of the blowpipe for the qualitative determination of minerals, and in the quantitative assay of silver and copper ores.

II. The second is a course of fifteen lectures on Descriptive Mineralogy, accompanied by critical examinations, and the handling of specimens on the part of the student.

ASSAYING.

The instruction in assaying is given by Prof. Richards in a course of ten exercises (of two to three hours each), in which the student learns to perform the ordinary dry assays of gold, silver, lead and other ores. Instruction in wet assaying is given by Prof. Crafts.

CHEMICAL COURSE FOR MINING ENGINEERS.

The chemical instruction of the mining-students extends through the four years. The course in General Chemistry occupies the first year; and during this time the students work two hours each week in the chemical laboratory. Each student performs for himself a great variety of experiments designed to illustrate the properties of the various chemical elements and of their more important compounds: he also prepares a number of such simple and compound substances as are of use in the arts or serve to illustrate the laws of chemical change. The knowledge thus acquired by the practical work of the laboratory is

supplemented and enforced by lectures, recitations and frequent examinations.

During the second year, more particular attention is given to the theory of Chemistry, and to Qualitative Analysis. The latter branch of the subject is taught by laboratory-exercises, each student working four hours a week. As during the first year's course, these laboratory exercises are accompanied by recitations and examinations.

During the third year the mining-students take a systematic course of quantitative analyses, occupying six hours per week in the laboratory, and attend a weekly lecture, or exercise in which methods of analysis are discussed, and the results of investigations too recent to be found in text-books are presented to them. Mining-students may take in addition, as a voluntary exercise, a course of special analytical methods, reciting from German text-books.

In the fourth year the students are engaged in laboratory-work during the hours between 9 A.M. and 5 P.M., which are not devoted to recitations and problems in drawing, metallurgy, etc., which more nearly concern their professional studies. They all get about three hours daily for chemical work; and many are able to spend more time in the laboratory without neglect of their other studies. They accomplish a tolerably thorough analytical course, comprising the analyses of salts, the more common minerals, and particularly of ores and metallurgical products, and extending as far as the more difficult analyses, such as the determination of all the constituents of cast iron or steel; so that a student in his professional work as a mining-engineer may be independent of the assistance of a chemist, and competent to deal with all ordinary investigations.

Some students, who show a special aptitude for chemistry, are encouraged to take up special investigations connected with metallurgy; and all accomplish work which may be considered a sufficient preparation for their professional career.

PHYSICS.

The instruction in Physics, extending through the first three years of the course, is given by Prof. Pickering. During the first two years the whole subject is thoroughly discussed mathematically and experimentally in lectures illustrated from the extensive collection of physical apparatus of the Institute.

In the third year the students enter the Physical Laboratory, and learn to use the different instruments and to perform a variety of experiments. Special attention is paid to the testing of physical laws by comparing the observed and computed results.

The students further carry on systematic investigations of particular subjects, during the fourth year, and pursue such courses of experimentation as have a direct bearing on their professional studies.

COLLECTIONS.

The geological collection of the late Prof. Henry D. Rogers of the University of Glasgow, presented to the Institute by Mrs. Rogers, is made up chiefly of fossils and rock-specimens from American localities, and in certain branches is peculiarly valuable for instruction. The collection of ores and vein-stones is already large and varied, and is constantly receiving additions from the various mining regions.

A typical set of models of mining-machinery, chiefly from Freiberg, Saxony, is used in the course of instruction. They are designed mainly to illustrate the principles of the various processes of mining and ore-dressing, but combine also the latest improvements in machines. They show in detail the methods of working underground by underhand and overhand stoping, the timbering and walling of shafts and levels, the arrangements of pumps, man-engines, ladder-ways, hoisting-ways, the sinking of shafts, etc. The machines for ventilation as well as those for ore-dressing are working models. The latter illustrate all the stages of the concentration of ores.

The collections and library of the Boston Society of Natural History are, by an agreement between the Society and the Institute, freely open to the students. These collections rank among the first in the country for extent and value, and in many departments are unsurpassed; the library is rich in works on Geology and Natural Science and embraces the leading American and European journals and periodicals on those subjects.

The instruction in certain subjects is given by the Professors of the Institute in the lecture-room of the Natural History Society, whose building is upon the same square with the Institute of Technology.

The private collections of some of the professors, especially that of Prof. Hunt (which is very complete in lithology and mineralogy), are available for purposes of instruction.

The Boston Public Library. The professors and students of the Institute are also allowed the full use of this extensive and valuable library.

REPORT UPON THE INSTRUCTION IN QUANTITATIVE ANALYSIS IN 1871-1872.

The opening of a new laboratory room has increased by about three-fifths the space devoted to the work of the third and fourth years' classes in Quantitative Analysis, so that the desk-room is amply sufficient for the ordinary work of classes of the present size.

It has, however, been found impossible to secure the small rooms, which should adjoin the main working rooms, and which should contain the more delicate pieces of apparatus, such as the balances, microscopes, spectroscopes and apparatus for gas-analysis. In default of these, a glazed partition has been thrown across a part of one of the laboratories, and in this way, without sacrificing the light of a window, a small room has been provided for the balances and the chemical library, which answers its purpose very well; but unfortunately it is not far enough removed from the laboratory to secure the balances from danger of injury from acid fumes, which occasionally escape into the air of that room as the result of an accident. The weighing room is also too small for laboratories provided like ours with places for forty-six students. The cases in which operations with acids are carried on, are connected with flues having an excellent draught, and thanks to them it has been found possible, with careful manipulation on the part of the students, to keep the air of the laboratories as pure as it usually is in such rooms; but this task is rendered irksome by a deficiency in proper ventilating flues opening directly into the rooms,

and by the fact that the rooms, having a low ceiling, offer a restricted bulk of air to deal with. These are defects which cannot apparently be remedied in the existing building.

Several new appliances for facilitating the laboratory work have been introduced during the past year. These include, besides improved forms of apparatus, some of those labor-saving contrivances, which may find their place in a laboratory as well as in a work-shop. Under Professor Ordway's directions several wrought iron steam boxes, capable of resisting a great pressure, have been purchased and set up. They are connected with the boilers used for heating the building, and when the steam is passing through them they serve as iron tables, which can be maintained at a constant temperature, and on which solutions to be evaporated can be left without danger of being over-heated.

One of the most remarkable improvements in analytical chemistry has been the introduction by Professor Bunsen, of Heidelberg, of an ingenious mechanical attachment to the ordinary filters, allowing them to be connected with a very simple air pump, worked by water and greatly accelerating filtration. A few such pumps had already been constructed in the school, after the discovery by Professor Richards of some important improvements in their form. This year one has been set up at each desk in the new laboratory, while means are provided to the student for making for himself the apparatus attached to the filters. These appliances have proved so easy to manage, so inexpensive, and of such value in shortening the time required for analysis, and consequently allowing the student to take a more extended course, that it is proposed to provide each desk in the old laboratory with them next year.

A new method of making copper assays, which has lately been tested with great thoroughness in Germany, has been successfully tried in the laboratory, and even beginners have obtained very exact results with it. The process depends upon the use of a galvanic battery, and a number of these of Meidinger's pattern, which remains in constant action many weeks,

have been set up in different parts of the laboratories. It was deemed that such processes would be of little use to the student in his after career, unless he could easily procure the necessary apparatus, and it was therefore considered an essential part of his instruction to suggest to him by examples, ways of supplying his needs with the commonest materials.

The batteries in question were made in the laboratory from pieces of lead pipe and broken bottles, and the perishable part, which is the zinc element, was cut from the thick plates of zinc, which have been introduced of late years for sheathing vessels. With a few hints in such directions a student may often supply himself at a small cost with apparatus that is not attainable ready made in this country; and in this connection may be mentioned a new apparatus for weighing hygroscopic bodies, made entirely by the students, of which an account will shortly be published; also the preparation by some of the students of their own measuring tubes for gas analysis, which are graduated by means of Bunsen's simple instrument, and the graduations are afterwards etched upon the glass.

In the absence of a proper room for gas-analysis, through Professor Pickering's kindness, a portion of the physical laboratory has been set apart for this purpose, a sufficient quantity of mercury has been purchased and instruction in this important part of a chemical course will be given next year.

As important additions to the laboratory apparatus may be mentioned a Hofmann's combustion furnace, and a new balance by Becker. A spectroscope by Steinheil of Munich, a saccharometer by Soliel of Paris, with quartz compensating prisms, and a very large and delicate balance by Lingke of Freiberg, have been placed at the service of those students who require them for any special purpose.

The progress of the students in their analytical work has been satisfactory, and a considerable number of them have voluntarily spent more than their required time in the laboratory.

The students who take the course in Quantitative Analysis are of two classes, those who take it as a part of their course in Mining Engineering, and those who make it their principal study with the intention of becoming chemists. It was felt that the distinction between the studies required in each course was not sufficiently marked, and that the chemical students had time to take up more of the theory and practice of chemistry, than the pressure of the other studies of the mining students would allow them to attend to during the last term.

By way of experiment two new classes were established; one a voluntary class of the third year's students, reciting from a small German text book upon some special subjects in analytical chemistry; the other comprised all the chemical students of the fourth year's class, as well as two volunteers, who were graduates of the school. The subject was organic chemistry, and it was looked upon from two points of view. In the first place an endeavor was made by using very advanced text books, and by giving citations from the chemical journals of the most important of the discoveries, more recent than the text books, to show the student where to look for the complete description of the facts, which subsequent work might require him to study, and at the same time to impress upon his memory the more important points, presenting them in relief against the minor ones. In the second place considerable attention was paid to the somewhat intricate theories of organic chemistry, in the belief that it is the best ground upon which to encounter and master the theories of chemistry in general.

The choice of text books was left free and the larger number in the class selected Kekulé, a work in German, and the most complete yet published on the subject. It was with some apprehension that this formidable text-book in a foreign language was attacked, but the experience of the term seems to approve the choice.

The lessons covered about twelve hundred pages octavo and of course the whole text was not even read in preparation for a recitation, but it was not difficult to select the more important statements; familiarity was gained with the arrangement of the

best guide to a complete knowledge of the subject, and a favorable position attained for beginning its thorough study as a specialist when separated from the assistance of a teacher. Some stress may be laid upon the value of the acquirement of the technical words in German during a course of study of this kind.

It is very possible that the class of this year were unusually well fitted to take up this subject, several of them reading German with ease, and certainly it would be premature to found a decided opinion about the best course for the future upon so short an experience; it has been determined, however, to require next year, for the chemical students of the third year's class, an additional course in a special branch of analytical chemistry from a small German text book (no good English one on the subject is procurable), besides the regular course of lectures on analytical chemistry, which are taken by the chemical and mining students alike; and in the fourth year's course, the chemical students willhave two recitations a week on organic chemistry, accompanied by lectures, and the choice of text-book will be left free. A written description has been given to the class of several text-books, and no advice as to a choice is given, even when asked. Success with one or the other depends so much upon the character of the person using the book, that it is thought desirable to leave the responsibility with each individual.

In conclusion, the fruits of the year's work which we can offer to the public, are two short investigations ready for publication, one made by a student of the graduating class who has shown an unusual aptitude for chemical work, another by one of the professors.

It is to be hoped that in the future a larger number of the students may be able to go over untrodden ground before finishing their course, and also that the laboratory may offer sufficient inducements to attract more experienced workers to make investigations there.

J. M. CRAFTS,
Professor of Analytical and Organic Chemistry.

June 3, 1872.

REPORT OF THE DEPARTMENT OF ARCHITECTURE.

President Runkle, Dear Sir:—

At the close of the fourth year in which this Department has been in active operation I beg to present the following account of its present condition, of what it has thus far accomplished, and of what had previously been done by way of preparation for this work.

This preparation had consisted chiefly in such examination as I had been able to give to foreign schools of architecture, with some personal consultation with architects both in this country and abroad, and in the collection of casts, photographs and drawings, and other materials, which the generosity of some friends of the school had given the means of purchasing. Some unusually favorable circumstances rendered these collections much more extensive and valuable than was reasonably to be expected, especially in respect to mediæval sculpture and carvings and architectural drawings. A large and almost unique collection of casts from Lincoln and Southwell fortunately fell into my hands, which, I was afterwards able to supplement by considerable additions from French Gothic work of the same period. At the moment of returning home I was also enabled, by the generosity of Mr. Ernst Benzon, of London, formerly a resident of Boston, to purchase an unusually good collection of school drawings, made by students in architecture at the Ecole des Beaux Arts, in Paris, and at the French Academy in Rome.

These collections were largely augmented by the kindness of many gentlemen, mostly architects, who, both in England and on the Continent, evinced a lively interest in our undertaking, and contributed not only photographs of their works, but tracings and lithographic copies of working drawings, with specimens of specifications, estimates, bills of quantities and various forms of business papers. Our thanks are specially due to Mr. Waterhouse, Mr. Withers, Mr. Keeling, Mr. Norton, Mr. Nash, Mr. Rickman, Mr. Edis, and the late Mr. Papworth in London, and Mr. Bryce in Edinburgh, and to M. Viollet le Duc, M. Charles Garnier and M. Lesoufacher in Paris, for their generous contributions. M. César Daly also presented to the department his valuable work illustrating the domestic architecture of the Second Empire, and the French Minister of Public Instruction, M. Duruy, acting through our Minister, Gen. Dix, put at our disposition a number of illustrated works relating to the architectural history of France, among which were the magnificent monograph of the Cathedral of Chartres and the two volumes entitled the "Statistique Monumentale de Paris." The Secretary of the Institute of Scottish Architects in Edinburgh also gave us a nearly complete series of the publications of that Society, the Architectural Publication Society of London added their miscellaneous publications, and the Royal Institute of British Architects not only presented us with a complete set of their valuable Proceedings, but were good enough to put us upon their books, so that we have continued regularly to receive the papers they have published. Altogether, besides these books and papers, the collections comprised, at the moment of opening the school, about 2,000 photographs, 500 prints, 400 plaster casts, 200 crayon drawings, 40 water-colors, mostly of architectural subjects, and 80 manuscript architectural drawings, large and small, besides 100 sheets of working drawings, mostly tracings, and some specimens of tiles, pottery and stained glass.

These various objects were classified and arranged in the rooms of the Architectural Museum during the spring and summer of 1868, and wall-catalogues giving the names of a

chief part of the plaster casts were printed for the convenience of visitors, of whom several hundred visited the Museum during the next year. On the opening of the Department at the beginning of the school year in October, sixteen pupils presented themselves, four of whom were special students in architecture within the school, spending their whole time over their school-work. The others were students or draughtsmen in offices, coming to the school only to attend lectures.

During this year the lectures were mostly historical and critical, as a part of the Course of Design, the Course of Construction not being undertaken. A course of lectures upon Perspective, however, was given in the course of the winter, which was attended by the whole of the Third Year's class. The work of the year, after some preliminary exercises in the use of india-ink and color, consisted of a series of problems in design, of gradually increasing difficulty, originated and worked out by the students under my advice and supervision; such as, among others, a Balcony, a Bridge, a Triumphal Arch, a Swimming Bath, a Mausoleum, a Chapel, and some problems of ornament, such as a Honeysuckle frieze, a four-leaved Corinthian capital, etc., etc.

The second year, beginning in October, 1869, I was fortunate enough to secure the services, as my assistant, of Mr. Francis W. Chandler, now Assistant Supervising Architect of the Treasury Department at Washington. Mr. Chandler had formerly been a student and draughtsman in my office, and had then just returned from the completion of his studies in Paris. He continued in the school until the first of April, spending his whole time in the drawing-room, giving the class just at the moment each might need it the benefit of his advice and assistance. The marked improvement made by the class under this arrangement convinced me, of what indeed hardly to my mind needed this proof, that the only way to secure rapid progress in this work is to have personal instruction from a highly accomplished teacher constantly at hand to save the students from the loss of time and trouble, which, in the beginnings of so

difficult and complicated a study must otherwise be very great. During the last part of the year the class were strong enough to get along without more constant supervision than I could myself give them. I, however, engaged the services of Mr. Langerfeldt to give them lessons in water-color drawing, and of Mr. Virgil Williams, who for several months gave them lessons in crayon drawing several times a week.

During this year there were twenty-two students attached to the Department, of whom twelve were students in offices, and only attended lectures. The other ten spent their whole time at the school as special students in Architecture, many of them taking in addition to their professional work some of the mathematical or other studies open to them in the school.

My own work comprised, besides the instruction given to the class in Design, of the same general character as the year before, a course of lectures in Construction, in which the ordinary detail of office work was gone over in connection with the specifications and working drawings. The work of the class, in like manner, comprised, besides the series of problems in design, the working drawings of a small frame house, with details and specifications, according to designs of their own. The problems in design embraced, among other things, a Campanile, employing the Doric, Ionic, and Corinthian orders; a Hospital and Alms House for 40 pensioners, with Chapel, Refectory, Hospital, etc., all with open roofs; a set of church furniture, font, pulpit, etc., etc.; a half-timbered house; a school and library building, with passage to a church beneath; a summer-house between two bridges; and a number of minor subjects. A considerable number of the drawings embraced in these series were drawn in perspective. Much of the work was in the Gothic style.

The Boston Society of Architects, "wishing to do its part in the work of architectural education," established this year two annual prizes, consisting of books, of the value of fifty dollars each, to be given to the students who should exhibit at the end of the year the best year's work. A committee consisting of Mr. Cabot, Mr. Cummings and Mr. Van Brunt, awarded the

prize for the best work in the class of Design to Joseph A. Pond, of Allston, and a committee consisting of Mr. Hartwell, Mr. Preston and Mr. Brigham awarked the prize for the best work in the class of Construction to William M. Woollett of Albany, N. Y.

The third year, from October, 1870, to June, 1871, the class numbered fourteen special students, many of whom were the same as the year before, with only two or three from the offices. Indeed, experience had shown that it was almost impossible for young men actively employed as draughtsmen to command time for any other stated avocation, by day. The attendance of this class of students had in the previous years been very irregular, ceasing almost altogether towards the end of the year.

The work resembled very closely that of the previous year, except that for accidental reasons, although the lectures in construction were carried on, the work done by the class under this head was but slight. The prize in construction was accordingly not awarded. That in design was given to Frank Spinning, of Dayton, Ohio. Mr. Langerfeldt and Mr. Williams continued their lessons in water-colors and crayon-drawing, and towards the end of the year the class had a course of a dozen lessons in modelling under the care of Mr. Alexander Johnston.

Mr. Chandler's engagements were such that, to my great regret and that of the class, he was obliged to relinquish part of his work at the school in January, and on the 1st of March gave it up altogether. It proved impracticable to supply his place either for the remainder of the year or for the year to come, very few young men in this country having the sort of training that fits them for school-work, and those few being in great demand for other work. In this case there seemed to be only one course left, and as soon as Paris was open to the mails I wrote to my correspondents both there and in London, begging them to employ their good offices to find among the young men about to leave the École des Beaux Arts some one competent and suitable for our vacant post. It was not until the month of December, however, that any definite result wa

reached, and it was January before I had the pleasure of welcoming my new assistant, Mr. Eugene Létang, and the satisfaction of sharing with him a labor whch I had borne almost without assistance since the preceding March.

This somewhat adventurous step, which from the circumstances of the case I was obliged to take almost upon my sole responsibility, has met with a success even greater than I had hoped. In professional attainments, I knew that of course a student of the *Première Classe*, a pupil of so eminent an architect and successful an instructor as Mr. Vaudremer, could not but be a thoroughly accomplished architect, and one thoroughly versed in the best methods of the best system of architectural discipline. Still, it is not without anxiety that one invites a foreigner to take part in our own undertakings, and in the present case there was cause to fear that the obstacle of language might prove an insuperable one. The event has proved, however, that these fears were unfounded. The awkwardnesses of the position have been met with tact and good sense, and as the young men have for the most part some knowledge of French, and are glad to practice what they know, what promised to be a source of embarrassment has been, in fact, a positive advantage. But of late English has again begun to prevail in the drawing-rooms.

The year's work has been of substantially the same character as before, except that during the last half of the year a considerable number of small problems, each occupying only a couple of days, or at most a week, have been introduced. The subjects of these have been, for instance, a Porch, a Carriage-Porch, a Portico in a Garden, a Peristyle, a Mantel-piece, etc., etc. The crayon or charcoal drawing has also, in Mr. Létang's hands, assumed a more prominent position, and the class have made good progress in it. I have also required the class every morning to bring in in their sketch books a pencil-sketch of some building, a plan, or an architectural detail, an exercise in every way salutary. A considerable part of the class have also done a fair amount of work in Descriptive Geometry, and in

shades, shadows and perspective, partly under my own instruction, and partly in connection with other departments of the school. The study of Detail Drawings has also been pursued with very satisfactory results, though to but a limited extent, in connection with lectures upon Carpentry and Joinery. It is impossible to go very thoroughly into these subjects without an entire interruption, for the time, of everything else. But in view of the fact that a chief part of the class were looking to spend a portion, at least, of their four months' vacation in architect's offices, it seemed best to do what could be done in preparation for that work.

The different topics embraced in the Lectures have been chosen so as to illustrate as far as possible the work the class might have in hand. These have been on Construction, on History and Criticism, on Shades, Shadows and Perspective, and the Perspective of Shadows, on the Composition of Mouldings, of Details and of masses; on the Orders, on the Topography of Rome, on the Tuileries and the Louvre, making about seventy lectures in all, delivered two or three times a week, and occupying an hour and a half or two hours each in the delivery. It has been necessary to give a good deal of information, *viva voce*, that might better have been obtained from text-books, if proper text-books were to be had. Indeed, a chief part of my own labor has consisted in collecting and putting into shape the common-places of architectural information, things which every architect knows, but which are not as yet accessible to students.

These various works occupied the first six months of the year, and sufficed for preliminary study. On the 1st of April a more important subject was taken in hand, which has occupied the rest of the year; the sketches and finished drawings for a Casino or Pleasure House, situated in a formal garden and surrounded with statues and fountains. This sort of subject, though remote from daily use and experience, is for that very reason best suited to this stage of advancement, as it necessitates the close study of the best masters, stimulates the fancy

and imagination, and does not involve the numberless considerations of practical detail, which it would not do to slight, and yet which the class are not yet prepared to entertain. A more practical problem would require for its solution a more extended experience than such a class can possibly have had. Work of this kind, on the other hand, while it taxes their powers to the utmost, both in the design and in the execution of the drawings, does not demand for its satisfactory performance any greater resources, either of knowledge or skill, than they have at command.

The result has amply justified this view, which is, indeed, supported by our own previous experience and by the practice of the best schools abroad. The progress of the class during these eight months, in the essentials of professional culture, has been very satisfactory. It is only by such incessant practice of original design, under proper guidance and criticism, that the creative and imaginative faculty can be exercised and developed. Moreover, it is through the varied manipulations which exercises of this sort exact, that artistic draughtsmanship is best acquired. Drawing thus becomes to the student not a mere mechanical exercise of hand and eye, but a means of expression, — a language by which to convey the architectural idea he has conceived in his mind.

The plans, sections and elevations which the class exhibit as the result of these two months' work are confidently presented in vindication of these views. They are in great part the work of students who had begun the study of architecture six months before. About half the class accomplished this work. The rest, who through absences or from other causes, were not strong enough to undertake it, have spent the time in exercises more suited to their condition.

Hitherto the classes in Architecture had consisted entirely of Special Students in this Department, most of whom had had no previous connection with the school. This year, however, two Regular Students presented themselves, young men, that is to say, who had been through the first two years' course, passing

all the required examinations, and who proposed to take, along with their architectural work, the further scientific studies requisite for a degree. This they have satisfactorily accomplished, and although they have not, of course, done as much Architectural work as the students who could give all their time to it, they have kept up with the class, and have constantly shown the value of the preliminary training the earlier years of the school had given.

The work of the Regular Course thus gone over, in connection with the Departments of Engineering, has comprised the elements of the Differential and Integral Calculus, and their application to Statics and Dynamics, illustrated by work in the Physical Laboratory, consisting of about a dozen practical problems in Friction, the Resolution of Forces, and the Deflection of Beams under various kinds of strain. These students have also done seventeen problems in Stereotomy, with the necessary drawings, and had instruction in Electricity and Magnetism, besides keeping up their exercises in French, German and English.

The Scientific studies of the Fourth Year will be less numerous, and will give Regular Students in this Department more time for their professional work. It will embrace a series of exercises in the Physical Laboratory, specially desired to illustrate architectural problems, and a course of lectures upon Building Materials, Mortars and Cements.

This development of our work promises to be a permanent one, several students of the present Second Year having signified their intention to become regular students in Architecture in the autumn.

The history of the last year was marked by an incident of special interest in the meeting in Boston of the Fifth Annual Convention of the American Institute of Architects, which, by invitation of the Institute of Technology, was held in the rooms of this Department. The opportunity of seeing so large a number of men, eminent in the profession, from different parts of the country, and of listening to their discussions, was keenly

enjoyed by the students. The Convention, in adjourning, besides making their acknowledgments for the courtesies extended to them, signified in strong terms their satisfaction and pleasure in observing the scheme of Architectural Education the Institute of Technology had set on foot.

The work of these four years, though in great part tentative and experimental, and full of the deficiencies that come from limited resources and limited experience has not been without its good results, and has been highly encouraging for the future. At the present moment, it may be claimed that the Department has fairly established itself in the confidence of the profession and of the community, and it may count upon a constantly increasing support and more extended usefulness. It is as yet too early to say how many students will be in attendance another year; but there is no reason to look for any diminution of numbers. On the contrary, the number who have already entered their names, and the frequent applications for information from students and architects in different parts of the country, seem to justify the expectation of a considerable increase. There is no doubt that we are better able than ever before to meet the reasonable expectations of the profession, and to furnish the instruction and discipline, of every sort, that an architectural education implies.

In this respect the proposed establishment in the School, of Post-Graduate courses of study, will be of special advantage to this Department, enabling us at the same time to extend the range of our work and better to arrange and classify it. As the professional work in the other Departments of the School is accomplished during the Third and Fourth Years, we have hitherto, in order to conform to them, had to set down the architectural work also, under the form of a two years' course; but to give notice that hardly in any instance could two years suffice to complete it. The extension of the period of study for an indefinite term after the regular course is finished will relieve us from this embarrassment. It will now be possible by exacting a certain amount of vacation-work and somewhat

diminishing the work set down to be done in connection with the classes in Civil Engineering, to give the regular students of these two years a sufficient knowledge of the elements of Architecture not to discredit the school — not enough to make them architects, even in the sense in which their fellows become at once Chemists and Civil Engineers, — but enough for Bachelors of Science, enough to enable them to pursue their further studies, in offices and in this Department, to the best advantage. This undergraduate work will thus be complete in itself, including all that relates to the scientific basis of the profession, giving all that an architect needs to know of Mathematics, Chemistry, Physics, Geology and Engineering, with as much of Architectural Drawing and of Architectural Design as can reasonably be comprised within the regular curriculum of a school of science.

The Post-Graduate course will then take up such special scientific topics as may prove desirable, with something of Practice; but it will be chiefly occupied with advanced work of composition and design, in continuation of that begun in the Third and Fourth Years. This work is perhaps more germane to a school of Art than to a school of Science. But it is a work greatly in demand, and one which we may ourselves take in hand with great advantage to our own undergraduates, to more advanced students, wherever trained, and to the community.

By the study of Practice is meant a systematic discussion of professional and business matters, such as contracts, specifications and working drawings, and the relations of architects to their clients and to their workmen. These topics are obviously, in the main, better suited to advanced students than to beginners, and a class fitted to take it up can go over this ground to very great profit in a limited period of time.

But for the main work of the Post-Graduate course, the study of Architecture as a branch of the Fine Arts, no period of time can be fixed, and no special curriculum assigned. Architecture in this aspect is not an exact science, and the methods appropriate to a school of science are less pertinent to this part of the

work than those of a school of art. Still it may be possible, without attempting to set any limit of time, nor to fix upon any course of study as in itself sufficient, to prescribe certain tests of attainment, as is done at the Ecole des Beaux Arts, by which the further honors of the school shall be governed. Just what these honors shall be, and by what rules they shall be awarded may best be left for time and experience to determine.

Such a course of architectural study, beginning with the preparatory work of the Undergraduate course, and extending in the Post-Graduate course over an indefinite period, should be made available, not only for the regular and special students, but for draughtsmen working on half time, or by intermittent and temporary engagements, in the architects' offices of the city. The great advantage to the school of securing such a class of students is obvious, and they should be received on such terms and for such periods as may best suit their necessities. Their work would naturally exhibit a seriousness of purpose and a command of resources that could not fail to act as a powerful stimulus upon their juniors, and to affect in the most favorable manner the tone of the school and its whole standard of performance. It is in this way, moreover, that the Department can best profit by the advantages of its position, in being established in a community where the practice of architecture is so excellent in respect both of construction and of design, and where the character of the profession is so respectable in point both of ability and of attainments. A practical familiarity with the work of the profession, which no schooling of course can give, must needs be sought in a good office, while the best discipline of an office needs to be supplemented by an academic training. If, by coming to Boston young men can combine both opportunities, and thus, in time, earn enough to pay their expenses as they go along, without foregoing the work of personal culture, they will not be slow in any part of the country in finding it out. To young men already well advanced in their professional studies,

the advantages of such an opportunity will hardly need to be insisted upon.

And in no other way, it seems to me, can we meet the reasonable expectations of the friends of the school, answer the higher demands of the profession, and do justice to our own position and resources. Architects so much need draughtsmen and assistants of all sorts that our students are constantly drawn off into office-work before we have begun to show what we can do with them. But we are prepared to give a first-rate architectural education, and the profession and the community are eagerly demanding young men who have received it. By enabling practicing draughtsmen to attach themselves permanently to the school, working upon an advanced class of problems during such leisure as they can command, during a term of years, the Department may hope to meet this want, and to vindicate its claims to a place among the agencies of a superior culture.

As time goes on and our needs are defined by experience, the deficiencies of our equipment in respect both of books and of models, begin to be keenly felt. It is very desirable that some regular provision should be made for supplying from year to year what proves to be most needed. The constantly increasing collections of the Engineering Departments are indeed of great service to us, especially in respect of Descriptive Geometry and Stereotomy, and the Trustees of the Public Library, in opening it to our students, and in promptly buying such new books as may be asked for, have given us every advantage which we could obtain from a library of our own. The establishment of the Museum of Fine Arts, also in the immediate neighborhood of the Institute, will presently put at our command extensive collections of works of art of every kind. But besides these resources we need to have certain things close at hand, in daily service. Books for consultation and constant reference, freely accessible to the students, are our most present want, and the more manifest deficiencies of all our collections need to be made good, and recent productions added. The generosity of the friends and patrons of

the school is, however, constantly doing much to relieve these wants, and the collections have considerably increased since their formation by various voluntary contributions. The most conspicuous of these additions is the stained glass, which has been partly purchased, but is in chief part the gift of the makers. It is arranged in four movable screens, and comprises work by Messrs. Morris & Co., Lavers, Barraud and Westlake, Heaton, Butler and Bayne, Clayton and Bell, J. T. Lyon and G. E. Cook in London, Cottier in Glasgow, and Cook and Mac Donald in Boston, besides some fragments of mediæval windows. Messrs. Maw & Co., of Brosely, Salop, have sent us four large squares of their mosaic and encaustic tiles, suitably mounted for exhibition, besides numerous smaller specimens, to which have been added a considerable number of painted tiles, chiefly by the glass-stainers just mentioned. We have also received from Dr. Salviati a gift of a capital specimen of his revived manufacture of Venetian glass mosaic, for which and for many other benefactions we are indebted to the good offices of Mr. R. P. Spiers, of London, one of our constant friends. Among other additions to the collections may be mentioned a complete set of the photographs of the original designs for the Law Courts in London, and a cast of the head of Michael Angelo's David at Florence, presented by Mr. Edward Atkinson. Mr. C. F. Shimmin has given us an early set of Hancock's reduced restorations of the friezes from Phigaleia and from the Parthenon. Mr. Hatfield and Mr. Wight also, architects of New York, sent us, on returning from the Convention in November, valuable additions to our stock of working drawings and specifications. Besides occasional purchases, our stock of books has been increased by a set of fourteen volumes of the "Illustrated London News," presented by Mr. F. H. Jackson, and the first seventeen volumes of the "Builder," by Mr. J. C. Hoadley.

We have also received an interesting collection of drawings, illustrating the system of black-board instruction in use in the public schools of Belgium, presented to the Institute by the municipal authorities of the Commune of St. Josse-ten-Noode,

Brussels, through Mr. Hendrickx, the originator of the system. The Trustees of the Boston Athenæum have also deposited with us, on loan, a number of casts of architectural details and models of buildings; and the Trustee of the Lowell Institute has, in like manner, given us the use of a large collection of lecture diagrams, a valuable addition to our resources in this particular, which, though constantly growing, are as yet far behind our needs.

Among the most interesting objects upon our walls have been the works of the students themselves, which have been regularly hung in the Eastern or Green Room, under the French drawings, remaining there until displaced by their successors. Some of the best of them have been photographed before being returned to their authors, with a view of forming a porte-folio of students' works.

These various subjects have not only been of service to ourselves, but have been freely used in the cause of art education, wherever, in the present deficiency of such appliances, they have promised to be useful. Especially in the evening drawing classes, recently established in Boston and other towns, and which have to a considerable extent depended for teachers upon the students in this and other departments of the School, they have done excellent service.

The whole undertaking has proved more arduous than it seemed at first, and constantly grows more and more difficult as we enter upon its higher paths. But from the point we have now reached we see more clearly the dangers we have escaped as well as the difficulties of the road before us, and the degree of success which, in spite of all shortcomings, has attended the efforts already made, is the best possible encouragement for the future.

The best work, of course, that a school can do is to discover and develope first-rate talent and to turn it towards the work for which it is best fit, and it is the aim and ultimate hope of this Department to attract the attention of young men of superior capacity, so to arrange its methods of instruction

as to stimulate their best efforts, and thus constantly to recruit the ranks of the profession with highly gifted, as well as with well-trained workmen. It is as yet too soon to say what measure of success may be reached in this regard, but the rapidly extending knowledge of the elements of art among all classes may justify the expectation that whatever germs of artistic power may exist in the community will be brought to light, and this Department may hope to do its part in their training. There is already reason to believe that we are not behind other nations in the quality of our raw material. The quality of our products will depend on the perfection of our educational processes.

I am, very respectfully,

Your obedient servant,

WILLIAM R. WARE,

Professor of Architecture.

REPORT ON THE INSTRUCTION IN STEREOTOMY AND MECHANICAL ENGINEERING.

To the President of the Institute:—

The instruction in Stereotomy is given by lectures illustrated by diagrams and models, combined with practical exercises in drawing and modelling. It is furnished to the students in Engineering and Architecture, and comprehends the making of such plans, elevations, sections, patterns, and working drawings as are essential for the erection of structures in masonry, wood, and iron.

MASONRY AND STONE CUTTING.

The instruction in masonry and stone cutting includes the study of arches of various forms and positions, as cylindrical, conical, and warped arches; full centered, segmental, and elliptical arches; right, oblique, and rampant arches. The structures illustrating this part of the course have included portals, niches, corbels, groined, and cloistered arches, domes, stair-cases, and oblique bridges.

DESCRIPTIVE GEOMETRY.

Exercises in the more difficult parts of descriptive geometry have occasionally been introduced to facilitate and ensure the employment of exact methods.

MODELLING IN PLASTER OF PARIS.

Sets of modelling tools are provided and practical exercises in modelling have been given; these consisted in executing from rough pieces of plaster, models of portals, oblique, and rampant arches, with the aid of patterns and drawings previously prepared by the students themselves.

It may not be out of place to state, that although this kind of modelling is taught in the European schools of engineering, no attempt has hitherto been made to teach it in this country.

Moulding in plaster has been taught to a limited extent.

STRUCTURES IN WOOD AND IRON.

The instruction in carpentry includes framing, bay work, the construction of roofs, etc. Examples of Mansard roofs, of English roofs, showing the combination of iron with wood, ensuring strength and durability; and the most approved forms of iron roofs according to the system of Polonceau, have been given.

Problems in construction and design, accompanied with numerical data, have been given to exercise the ingenuity of the student, and put to a practical test his acquired knowledge and skill.

GRAPHICAL WORK.

Graphical exercises have been given to each student beginning with an exercise in descriptive geometry as follows:—

PROGRAMME OF THE FIRST PROJECT IN THE APPLICATION OF DESCRIPTIVE GEOMETRY TO THE ARTS.

Intersection of a Surface of Revolution by a Plane.

A torus, the radii of whose generating and directing circles are respectively r and R, and the distances of whose centre from the planes of projection a and b, is intersected by a plane. This plane has a declivity t; its horizontal trace making an angle α with the ground line, is at a distance d from the axis of the torus. (a = distance above H.P. b = distance in front of V. P.)

The students will present,

1st. A drawing containing the two projections of the intersection of the plane with the torus, with one or more tangents to the limiting curve. The section should be colored according to the conventional tint.

2d. A drawing containing the curve and its tangents in their own plane.

3d. A memoir, explaining fully the principles and processes of the solution, the method in detail for tracing upon the solid in relief the curve of intersection, for cutting the solid, and for testing the accuracy of the section. [The pattern for verification should be constructed from the 2d drawing.] The students will use the following numerical data in alphabetical order.

R =	2·16	2·24	2·32	2·16	2·24	2·32	2·16	2·24	2·32
r =	1·12	1·20	1·28	1·28	1·20	1·12	1·20	1·12	1·20
α =	45°	46°	47°	48°	49°	45°	46°	47°	48°

$t = 0{\cdot}5 \qquad a = 2{\cdot}00 \qquad b = 4{\cdot}00 \qquad d = 4{\cdot}00$

This exercise is varied by substituting for the plane or the torus, or developable, double curved, or warped surfaces.

Then follow the exercises in masonry and stone cutting executed by each student.

Each drawing contains the plan, elevation, profile, section, and development (if possible) of the arch, with the patterns of the joints.

These exercises are as follows: —

1. Right cylindrical arch.
2. " portal in a battering wall.
3. Full centered oblique portal.
4. " " portal in a round tower.
5. Spherical niche.
6. Solid corbel (known by the name of *Trompe.*)
7. Vaulted conical portal.
8. " portal (known as *Arrière vousure de Saint Antoine.*)
9. " portal (" " " " *de Marseille.*)
10. Groined arch.

11. Cloistered arch.
12. Dome.
13. Exercise to illustrate the properties of the warped surfaces.
14. Spiral staircase.
15. An original exercise with numerical data, illustrating the intersection of one arch with another of a different size.
16. Oblique bridge. Helicoidal System.
17. Rampant arch.

EXERCISES IN MODELLING.

The students this year have made three complete models:

1. A vaulted conical portal.
2. A rampant arch.
3. An oblique arch.

EXERCISES IN CARPENTRY.

1. Construction of a Mansard roof.
2. Construction of an English roof, illustrating the combination of wood with iron.
3. Bay work.
4. Construction of an iron roof according to the system of Polonceau.

[This last problem has not yet been completed.]

MECHANICAL ENGINEERING. — THIRD YEAR. — FIRST TERM.

The instruction in Mechanical Engineering commences with Cinematics, or the study of motions as exhibited in machines, and treats of the composition and resolution of such motions, and their graphical representation by means of curves, which serve to show the spaces, velocities, accelerations, and paths of the moving points or pieces. Applications of these principles

are at once made in the construction of cams and sliding pieces. Next, the properties of rolled curves, with the exact and expedetive methods for their delineation, are explained and applied in the construction of all kinds of gearing.

PRINCIPLES OF MECHANISM.

The principles of mechanism are next taught according to the system of Willis. The study begins with simple elementary combinations, and is extended so as to include the various contrivances for modifying the motion or the path of a moving piece, such as epicyclic trains, parallel motions, speed cones and pulleys, universal joints, link motions, etc., etc.

A recent examination paper is here introduced to illustrate the instruction, which varies from year to year as improvements suggest themselves.

SEMI-ANNUAL EXAMINATION. THIRD YEAR.

CINEMATICS.

1. *Helical motion.* Investigate the motion of a body rotating around a given axis, and moving at the same time parallel to this axis.

Example. A body makes 40 revolutions per minute, and has at the same time a velocity of translation $4\frac{1}{2}$ times its angular velocity. Determine the trajectory, as well as the direction and velocity of a point 6 ft. from the axis of rotation.

2. *Combined Parallel Rotations.* Let a plane passing through a fixed axis O, rotate about it with a given angular velocity a. Let C be a second axis in that plane, and parallel to the fixed axis O; and about the moving axis C, let a rigid body rotate with an angular velocity b relatively to the plane OC. Show how to find the position of the instantaneous axis and the resultant angular velocity.

3. *Curvature of the Epitrochoids.* Deduce the radii of curvature of the following curves employed in the construction of the teeth of wheels:

The Epicycloid, the Trochoid, the Cycloid, the Involute of the Circle, the Archimedian Spiral.

4. *Rotations about Intersecting Axes Combined.* Let OA be an axis assumed as fixed, and about it let a plane passing through OA

rotate with an angular velocity a. Let OC be a second axis in that plane and intersecting the first axis at O; about the moving axis OC let a rigid body rotate with an angular velocity b. Show how to find the position of the instantaneous axis, the surface it describes, and the resultant angular velocity.

Bevel Wheels. Two axes intersecting at an angle of 80° are to be connected by a pair of bevel wheels: one axis is required to make three revolutions to one of the other. The largest radius of the pinion is 12 in.; this pinion is to have 44 cast iron teeth. The teeth of the wheel are to be of wood, and the width measured along the pitch surfaces is to be 5 in. The profiles of the teeth are to be involutes of the circle; and finally there must always be at least one pair of teeth on the first in contact with a pair on the second wheel. Show how to lay out the teeth.

5. *Combined Rotation about Axes not in the same Plane.* A rigid body rotates with an angular velocity p, around a given axis A in space; this axis revolves around a second given axis B, not in the same plane with the first, with an angular velocity q. Required the resultant angular velocity, the position of the instantaneous axis, and the surface it describes.

Skew bevel Gearing. It is required to connect two perpendicular axes not situated in the same plane by a pair of skew bevel wheels. The shortest distance between the axes is 12 in.; the least diameter of the pinion must be 24 in.; it must have 72 teeth 6 in. in width, measured along the pitch surface. The profiles of the teeth are to be formed by epicycloids and hypocycloids.

6. *Non Circular Wheels.* What are the geometrical conditions that must exist between a pair of rotating surfaces, in order that they may move in rolling contact round fixed axes?

Example. The equation of the base of a cylinder rotating around a fixed axis is $\log. r = A\theta + B$; what must be the equation of the base of a second cylinder rolling in contact with the first and rotating around a second fixed axis.

7. *Sliding of Teeth.* Given the arcs of approach and recess, to find the amount of sliding of one tooth over another.

8. *Sliding of Involute Teeth.* Find the amount of sliding of two involute teeth, supposing the tangent to the base circles to make an angle of 75½° with the line of centres.

9. *Adendum of Involute Teeth.* Show how to find the adendum for involute teeth.

10. *Swash-Plate.* Find the equation expressing the motion transmitted by the swash-plate.

Show how to make a cam which will give the same motion.

11. *Cams.* Show how to construct a cam which shall give any assigned motion to a moving piece. Given $s = f(t)$.

Example. Make a cam which shall give exactly the motion of an eccentric.

MECHANISM.

12. *Wheels in Trains.* Suppose two axes are to be connected, whereof one revolves once in 24 hours, and the other in 362 days 5 hrs. 48 min. 48 sec., show how to arrange the train.

13. *Screw-Cutting Lathe.* What train should be used upon a screw-cutting lathe with a guide screw of $\frac{1}{4}$ an inch pitch, to cut a screw with $13\frac{1}{4}$ threads to the inch?

14. *Least number of Axes.* Given the value of a train, the least number of teeth allowed upon a pinion, and the greatest number allowed upon a wheel, to find the least number of axes.

Example. Required the least number of axes in a train of wheels which shall cause the last axis to revolve 180 times as fast as the first axis, allowing that none of the drivers contain more than 54 teeth, and none of the followers less than 9.

15. *Epicyclic Train.* Deduce the general formulæ for finding the value of epicyclic train.

Example. Ferguson's Paradox.

16. *Parallel Motion in Gorgon Engines.* Explain the theory and construction of the parallel motion used in a certain class of marine engines, known as Gorgon Engines.

The above instruction is completed in four months, and is followed by a course on the dynamics of machinery.

DYNAMICS OF MACHINERY. — THIRD YEAR — SECOND TERM.

This comprehends the estimation and measurement of force and power; the application of the principles of virtual velocities to machines; the theory and use of the indicator and dynamometer; the estimation of the effects of centrifugal force; the determination of the safe speed of rotation for fly wheels, mill stones, polishing stones, etc.; the method of balancing locomotives to prevent dangerous oscillations when running at high speeds; the estimation of the effects of fluctuations of speed; the study of regulating apparatus, as fly-wheels, governors, cataracts, brakes, etc; the computation of the loss of power due to secondary resistances; resistance of friction; estimation of the loss of mechanical effect, occasioned by the friction of journals, pivots, teeth, screws, cords, belts, chains, etc.

To illustrate this last important subject, a powerful machine is taken and the loss of power on account of the friction of each piece is successively calculated, and the efficiency of the whole machine deduced.

GRAPHICAL WORK.

The instruction in making sketches and finished drawings of machinery from models, and from actual machines is continued during the third year, but in addition to this, numerical and graphical problems pertinent to the subjects of the lessons are given from time to time: such as the construction of cams, excentrics, link and valve motions, and all kinds of gearing.

This is followed by exercises in drawing complete machines from given numerical data. For this purpose, liberal use is made of the collection of models belonging to this department.

At end of the year an examination over the whole course is held. The following is an examination paper:

ANNUAL EXAMINATION—THIRD YEAR.

MECHANISM.

1. *Epicyclic Trains.*

Deduce the general formulæ for finding the value of an epicyclic train.

Example.—Explain the *differential motion* of the bobbin and fly frame, in cotton spinning machinery, and calculate the velocity ratios of the bobbin and the flier corresponding to several different positions of the belt upon the speed cones.

2. *Watts' Parallel Motion.*

Explain the theory and construction of the parallel motion used in beam engines, or in side lever marine engines.

3. *Boring Machines.*

Explain the machinery used for boring steam cylinders.

Example.—Show how to arrange a train with the guide screw of $\frac{1}{4}$ an inch pitch, so that the cutter shall advance $\frac{1}{11}$ of an inch for every revolution of the boring bar.

4. *Speed Pulleys.*

Open Belt.—Find the length of an open belt upon a set of speed pulleys.

Example.—Let the diameters of two speed pulleys be 4, 6, 8, 10, 12 inches respectively and the distance between their centres 6 ft. Find the difference in length of belt required for the pulleys 12 and 4, and that required for the pulleys 8 and 8.

Crossed Belt.—Find the length of a crossed belt for the above system of pulleys and show that it will fit any pair of the speed pulleys with perfect exactness.

DYNAMICS OF MACHINERY.

5. *Friction of an Axle.*

Example.—A water wheel weighs 30,000 lbs., the radius of its circumference is 16 ft., and that of its gudgeon is 5 in.; how much force is required at the circumference of the wheel to overcome the friction, or to maintain it in uniform motion when running empty, and how great is the corresponding expenditure of mechanical effect when it makes 5 revolutions per minute? Co-efficient of friction 0.075.

6. *Friction of a Pivot.*

Find the moment of friction of a pivot.

1st. General case in which the equation of the longitudinal section is $y = f(x)$.

2d. Flat pivot.

Example.—A Turbine weighing 1800 lbs. makes 100 revolutions per minute and the diameter of the base of the pivot is 1 inch, how much mechanical effect is consumed in a second by the friction of this pivot? Co-efficient of friction = 0.10.

3d. Schiele's anti-friction pivot (Tractrix). Find the moment of friction.

7. *Effects of Centrifugal Force.*

Example.—The dimensions, density, and strength of a mill-stone are given; required the angular velocity and number of revolutions per minute, which will cause rupture in virtue of centrifugal force. Radius of the mill stone 2 ft.; radius of the eye 4 in. Modulus of rupture 720 lbs., specific gravity 2.5.

8. *Fluctuations of Speed.*

Determine the coefficient of fluctuation of speed in a machine.

Example.—The fly wheel of an engine of 85 horse power makes 20 revolutions per minute, its diameter is 20 ft., and its weight 20 tons. If the engine were employed to lift a tilt hammer weighing 4000 lbs., the centre of gravity of which is raised 3 ft., and if this were done merely by the work accumulated in the fly wheel what part of its angular velocity would it lose?

9. *Rankin's Isochronous Gravity-Governor.*

Find the relations between the dimensions, the revolving mass, the load and the speed.

10. *Efficiency of Teeth.*

Find the efficiency and counter-efficiency of a pair of spur and a pair of bevel wheels.

Example.—A force of 912 lbs. is applied to the circumference of a pair of spur wheels having 221 and 111 teeth respectively. The co-efficient of friction is 0.10. What is the counter-efficiency and what force is transmitted to the second wheel?

FOURTH YEAR.—FIRST TERM.

The instruction comprehends:—

The examination of the materials used in Machinery, viz.: iron, steel, other metals and their alloys, wood, leather, hemp, etc.; their uses, defects, and the methods of preserving them from rust and decay; their moduli or coefficients of strength, elasticity and stiffness.

RESISTANCE OF MATERIALS.

This includes the estimation of the strength and stiffness of pieces exposed to tensile, shearing, bending, and twisting strains; factors of safety; calculation of the strongest forms of pieces; practical approximations to these; the effects of shocks and vibrations; the estimation of the strength of structures of stone, wood, and iron, as foundations, beams, columns, roofs, etc.; theory of continuous, and bowstring girders.

This portion of the course, which is thoroughly illustrated with practical examples, is followed by the students of Architecture, as well as those of Mining and Mechanical Engineering.

SEMI-ANNUAL EXAMINATION.—FOURTH YEAR.—COURSES I, III, IV.

1. *Extension.* Deduce the general formulæ for extension and compression, and solve the following problem:—

What must be the upper cross section of a wrought iron beam of the strongest form, 1000′ in length, when, besides its own weight, it has to sustain a load of 75,000 lbs.?

What will be the elongation?

Modulus of Tenacity, T = 10,000 lbs. Modulus of Elasticity = 29,000,000 lbs. Weight of inch bar wrought iron per running foot = 3.34 lbs.

2. *Resilience.* Compute the work necessary to extend or compress a given beam or shaft.

Example. The pumping apparatus of a mine is connected with the engine by means of a series of wrought iron rods 200′ long;

the section of each rod is $\frac{3}{4}$ of a square inch; the strain is estimated at 6 tons. How many units of work are expended at each stroke in the elongation of the bars? Modulus of Elasticity = 29,000,000 lbs.

3. *Flexure and cross breaking.* Investigate the case of a beam built in at one end, supported at the other, and uniformly loaded.

4. Apply the foregoing investigation to the theory of *continuous girders*, and solve the following problem:

A wooden beam 40′ long, bearing a load of 500 lbs. per running foot, rests upon three equidistant supports, what must be the dimensions of the beam? Modulus of working load 1000 lbs.

5. *Compression.* If in the last example the centre support were a wooden post, what should be its diameter if the modulus of rupture be 6500 lbs., and a six-fold security allowed?

6. *Torsion.* Deduce the formulæ to determine the strength of shafts to resist torsion.

Example. The cast iron, upright axle of a turbine exerts at the circumference of a cog wheel, 30″ in diameter, keyed to this axle, a force of 2500 lbs. What diameter must be given to the shaft? Modulus of rupture 27,000 lbs., and a six-fold security to be allowed.

7. *Timbering in a mine.* At what distance from each other must the 10″ stretchers be laid to support a pile of refuse 60′ high of an over hand stope, in a vein 4′ thick, and dipping at 70°? The weight of a cubic foot of material to be supported is 65 lbs.; the coefficient of friction upon the supports is $\frac{1}{3}$.

8. *Calculations for the establishment of a bowstring girder.* A bowstring girder, consisting of two beams 12′ long, 4″ high and 12″ wide, with diagonal braces and vertical struts, is supported at the extremities and loaded in the middle; the greatest opening between the beams is 10″.

What is the moment of flexure of the *upper beam* unloaded, caused by the middle strut?

What is the radius of curvature of its mean fibre, and the relative elongation of the extreme fibre?

What is the radius of curvature of the *mean fibre of the girder*, and its relative elongation?

What weight will the girder bear with safety? Modulus of strength = 12,000 lbs., and a three-fold security allowed.

Compute the increase in strength due to the struts and bracing.

The following additional questions were given to the class in Mechanical Engineering.

9. *Strength of an axle.* A round, wooden axle of a water wheel, 10′ long, has to sustain the wheel together with its own weight, and a uniformly distributed load of 10,000 lbs. What diameter must the axle have? Modulus of strength 10,000 lbs., and a ten-fold security to be allowed.

10. *Limit of speed.* Given the radius and section of the rim of a fly wheel, it is required to find the number of revolutions per minute, which will cause rupture from the action of centrifugal force. How many revolutions per minute can it make with safety?

11. *Dimensions of fly wheels.* Given the energy stored in a fly wheel, the number of revolutions per minute and the weight of the rim, to find the mean radius and section of the rim.

12. *Strength of gear wheels.* Given the radius of the pitch circle of a gear wheel transmitting N horse power, and the number of revolutions per minute. Show how to calculate the pitch, number of teeth, their dimensions and those of the rim.

13. *Effect of fluctuations of speed.* The fly wheel in a rolling mill is connected with the rolls by a pair of spur wheels. At the instant at which the blooms pass under the rolls (according to the experiments of Morin), a fluctuation of speed occurs of one-thirtieth, which lasts about one-seventh of a second. Suppose the number of revolutions of the fly wheel to be 70 per minute; let the energy stored in its rim be estimated at 3,600,000 ft. lbs., what would be the pressure thus occasioned on the teeth of one of the spur wheels, having a radius of 3 ft. 8 in., and situated on the same shaft as the fly wheel?

FOURTH YEAR. — SECOND TERM.

CONSTRUCTION AND ESTABLISHMENT OF MACHINES.

This comprehends: —

The calculation of the strength, the requisite proportions and dimensions of the parts of machines, viz., those exposed to shearing stress, as rivets, pins, keys, wedges, gibs, cottars, bolts,

screws, etc.; those exposed to tensile strain, as cords, bands, rods, links, etc.; those exposed to shocks, and combined bending and twisting actions, as shafts, journals, cranks, rims, arms, teeth, etc.; the computation of the straining effects due to the power; allowance for the centrifugal tension of bolts, of wheels and pulleys; centrifugal whirling of shafts.

To illustrate this part of the course a powerful machine is selected, and the calculations made to determine the stress upon each piece, and the proper proportions and dimensions which should be given to it.

THE PRINCIPLES OF THE ACTION OF CUTTING TOOLS.

Description of shearing, paring and scraping tools; proper angles and speed for different kinds of work; estimation of the work done in dynamical units; combinations of cutting tools; advancing and transverse feed motions; machine tools — punches, lathes, drills; planing, slotting, shaping machines, etc.

ANNUAL EXAMINATION FOURTH YEAR.

CONSTRUCTION OF MACHINES.

1. *Straining effects of Reaction.*

Example.—A piston and its appendages weigh 300 lbs., the length of the crank is 15 in., the number of revolutions per minute is 60. Required the straining effect due to the accelerating force of the steam on the piston.

2. *Strength of Belts. Centrifugal Tension.*

Example.—Suppose a belt moving over a suitable pulley with a velocity of 600 ft. per miuute, transmits a work of 5 horse power. Required the centrifugal tension, the tension due to the force transmitted, and the proper width of the strap.

3. *Strength of Axles.*

Example.—The crank at the end of a shaft receives and transmits a work of 50 horse power; this shaft rests upon two bearings 6 ft. apart, and carries one of a pair of spur wheels; this wheel situated at a distance of 5 ft. from the journal next the crank, weighs 3000 lbs., makes 35 revolutions per minute, and has a diameter of 14′ 8″. Find

the proper dimensions of the journal next the crank, taking into account; 1st, the force transmitted; 2d, the weight of the wheel; 3d, an approximate value for the weight of the axle; 4th, the reaction of the teeth of the wheel against its pinion. Show whether at this velocity the oil will be decomposed by overheating. Show also whether the pressure between the surfaces in contact is sufficient to expel the oil.

4. *Transverse Vibration of Pieces.*

Example.—1st. A pine rod 1 centimetre square, supported at two points 1 m. apart and loaded by a weight of 1.37 k. is deflected 0.032 m. What is its modulus of elasticity?

2d. The same rod was then loaded at the other end with a weight of 0.321 k. and put in vibration. The number of single vibrations in 30 seconds was 100. What was the modulus of elasticity?

ACTION OF CUTTING TOOLS.

5. Determine the pressures and the work performed by shearing and cutting tools.

Example.—What force does a punching machine exert in punching a hole through plate iron $\frac{1}{2}''$ thick, for a rivet $1\frac{1}{2}''$ in diameter? What amount of energy is expended? $f = 50{,}000$ lbs.

6. *Resistance and Work of Paring Tools.*

Compare the work of the machine with that of lifting the materia pared off.

HYDRODYNAMICS.

7. *Impulse of Water on Vanes. Flat Vane.*

Example.—A stream of water whose cross section is 40 square inches, delivers 5 cu. ft. per second, and strikes normally against a flat vane, which moves away with a velocity of 12 ft. What is the impulse? The mechanical effect? What velocity must the vane have to produce the maximum effect? Required the mechanical effect, the pressure, and the efficiency due to this velocity.

HYDRAULIC MOTORS.

8. *Poncelet's Floats.*

Describe and give the theory of Poncelet's floats.

9. *Floating Mill Wheels.*

Find the mechanical effect of a wheel in an open current.

10. *Turbines.*

Give the theory of the turbine; compute the energy exerted by the water on the wheel, the energy expended, and the efficiency of the motor.

COURSE ON THE STEAM ENGINE AND OTHER PRIME MOTORS.

This course is given to all the students in Engineering, and comprehends the measurement of force and power; the theory and use of the indicator and dynamometer; the estimation of the resistance of friction in machines, and the principles of hydraulics pertaining to the construction of hydraulic machines and motors.

PRINCIPLES OF HYDRAULICS.

These comprise the measurement of water power; the computation of the discharge over weirs, through orifices and sluice gates; the estimation of the resistance in pipes due to friction, bends, mouth pieces, etc.; the calculation of the mechanical effect due to the impulse of water upon vanes of various forms, and moving in directions oblique to the jet; the computation of the speed of the vane to give the greatest efficiency; the best form of vane to receive a jet; the effect of friction during the impulse; the effect of centrifugal force.

HYDRAULIC MACHINES AND MOTORS.

The description of each hydraulic machine illustrated by models and diagrams; the theory of its action, and the calculation of its efficiency. These machines include the hydraulic press, single and double acting water pressure engines, water wheels, floating mill wheels, turbines, reaction wheels, etc.

PNEUMATIC MACHINES.

The description, theory, and the calculation of the efficiency of machines accumulating or using power by means of com-

pressed air; as the Chemnitz machine, the compressing pumps and engines employed in tunnelling Mt. Cenis, etc.

PROPERTIES OF STEAM AND GAS. — EFFECTS OF HEAT.

The results of Regnault's and Fairbairn's researches on the relations between the temperature, pressure, and specific volume of saturated steam; the results of Zeuner's researches on superheated steam; the computation of the loss of heat by radiation, according to the experiments of Peclet; the effect of jacketing; the computation of the heat thus economized per hour; the calorific power of different kinds of fuel; the total and available heat of combustion; the quantity of air required for combustion and dilution.

BOILERS, FURNACES AND FIRE GRATES.

The description and general arrangement of a furnace and boiler; the strength and construction of boilers; the total and effective heating surface; the water and steam room; the computation of the dimensions of a boiler to produce a certain quantity of steam per hour at a given pressure; the efficiency of a furnace; the efficiency of the heating surface; the requisite amount of grate surface.

STEAM AND GAS ENGINES.

The estimation of the work of the steam in an expansive steam engine: 1st, when the pressure is supposed to vary according to Mariotte's law; 2d, when the pressure is supposed to vary according to Laplace and Poisson's law; the efficiency of different kinds of engines; the estimation of the quantity of steam, feed water, and fuel, requisite to supply an engine running at a given speed with a given pressure of steam; the calculation of the effective work on the crank shaft; the theory of the slide valve, (Zeuner's graphical method); the expansion valve; the gas engines of Lenoir and Hugon; the recent improvements in this direction, with the binary steam and vapor engines.

This course has been illustrated throughout with numerical examples.

The following examination papers of last year are annexed:

MACHINERY AND MOTORS.—FIRST EXAMINATION FOURTH YEAR.

MEASUREMENT OF THE DYNAMIC EFFECT OF MACHINES.

1. *Dynamometer.* Explain the theory of Proney's friction dynamometer, and apply it in the solution of the following problem:

To determine the effect of a water wheel, a friction dynamometer was placed on the shaft when the water let on had been perfectly regulated for six revolutions per minute; the weight in the scale pan, including the reduced weight of the instrument, was 530 lbs., the leverage of this weight was 10.5 ft. What was the horse power of the wheel?

2. *Indicator.* Explain the theory of the indicator, and apply it in the solution of the following question:

A double acting expansive steam engine has two indicators, one at each end of the cylinder. The breadths of the diagrams given by each, measured on a scale representing pounds on the square inch, are as follows:

Top, 27, 83, 91, 91, 64, 57, 53, 42, 35, 22, 13; bottom, 36, 97, 96, 84, 64, 57, 46, 40, 32, 22, 12; the area of the piston is 345 square inches; the length of stroke is 30 inches; the number of revolutions per minute is $52\frac{1}{2}$; what is the indicated horse power of the engine?

3. *Brake.* Explain the theory of the flexible brake, and apply it in the solution of the following question:

To let down a shaft a load of 1200 lbs. from a certain height, the rope to which this weight is attached is wrapped $1\frac{3}{4}$ times about a round, firmly clamped holder, and the other extremity is held by the hands; with what force must this extremity be stretched that the load may slowly and uniformly descend? Let the coefficient of friction, $f = 0.3$.

HYDRAULICS.

4. *Discharge through a rectangular orifice.* Example. If a rectangular orifice is 3′ wide, $1\frac{1}{4}$′ high, and the lower edge lies $2\frac{1}{4}$′ below the surface of the water, what will be the discharge per second?

5. *Friction of the water in pipes.* Example. What discharge will flow through a pipe 2″ in diameter, under a head of 3′ of water, when the coefficient of resistance, owing to the friction in the pipe, is 0.40.

ÆRO-DYNAMICS.

6. *Work of Expansion.* Compute the mechanical effect produced by the expansion of a given volume of air or steam.

Example 1. The inner diameter of the cylinder of a high pressure, double acting steam engine, without expansion, is 18″, the number of revolutions per minute 24, the length of stroke 40″. The steam gauge stands at 32.25 lbs. The barometer indicates the pressure of the atmosphere to be 14.1 lbs. What is the pressure on the piston, and what is the power of the engine?

Example 2. In the last example what would be the horse power of the same engine, working expansively, the steam being cut off at .4 of the stroke?

How much more steam would be used in the first case than in the second?

State the relative economy in using steam expansively.

7. *Compressing Engine.* Make a sketch of the compressing engine (*Compresseur à choc*) used at the Mt. Cenis tunnel for supplying compressed air to the boring machines. Give the theory of this engine, and calculate its efficiency. Diameters of the tubes 0.62 metres; height of the column of air compressed at each stroke 4.05 metres; height of the fall, 26 meters; pressure of the atmosphere 10.330 metres; pressure in the manometer 7 atmospheres after each stroke.

8. *Compressing pump.* Make a sketch of the forcing pump (*Compresseur à pompe*) used for the same purpose. Give the theory of its working, and calculate its relative and absolute efficiency, supposing it to be driven by an overshot water wheel, using 60 cubic metres of water per minute, with a fall of 5.60 metres. Diameter of the pump 0.57 metres; length of stroke 1.20 metres; number of strokes per minute 16; manometric pressure 7 atmospheres. Assume the efficiency of the water wheel to be 75 per cent.

9. *Safety Valve.* Find the effective pressure necessary to open the safety valve and solve the following problem:

The statical movement of an unloaded safety valve is 10 inch lbs.; the sliding weight, 15 lbs., has a leverage of 10″; the arm of the valve measured from the valve to the fulcrum is 4″; the radius of the valve is 1.5″; what is the pressure per square inch on the valve?

HYDRAULIC MOTORS.

10. *Water Pressure Engine.* Calculate the principal parts of a single acting water-pressure engine used to drain a mine.

Given depth of the mine, h = 230 metres; quantity of water flowing in per minute, q = 1.792 cubic metres; source of power, a fall, H = 60 metres, giving a quantity, Q = 20 cubic metres per minute. Loss of head due to friction, bends, valves, etc., $k' = \frac{1}{3}$. Loss of water on account of the pierced valve, $k'' = \frac{8}{10}$. Assume the length of stroke, Z = 2.3 metres; the number of strokes, n = 5½ per minute, and limit the velocity of flow through the supply pipe to 2 metres per second. Calculate also the size of the supply pipe and the diameter of the forcing pump.

11. *Effect of Centrifugal Force.* Effect of the centrifugal force on an overshot water wheel.

Example. An overshot water wheel 32′ in diameter makes 5 revolutions per minute, what angle does the surface of the water in the bucket at the extremity of a horizontal diameter make with a horizontal line?

12. *Poncelet's Water Wheel.* What should be the curve of the longitudinal section of the head race for Poncelet's water wheel?

SECOND EXAMINATION.

HEAT APPLIED TO AIR AND STEAM.

1. *Combination of the laws of Mariotte and Gay Lussac.*

Example.—If 800 cu. ft. of air at a temperature of 10° C., and at a pressure of 15 lbs., are brought by means of the blowing engine and warming apparatus of an iron furnace to a temperature of 200° C., and a pressure of 19 lbs., what volume will it assume?

2. *Specific Volume of Saturated Steam.*

Example.—What quantity of feed water does a boiler require to produce 500 cu. ft. of saturated steam at a pressure of 3 atmospheres?

3. *Specific Volume of Superheated Steam.*

In the last example let the steam be superheated to 150° C, and at the same pressure; what will be the amount of feed water then required?

4. *Peclet's Law of Cooling.*

Example.—A wrought iron boiler contains water at a temperature of 100° C., and has a surface of 15 square mtrs. exposed to the air at 20° C.; what hourly cooling takes place?

Effect of the Jacket. If the same boiler had a jacket of 25 square mtrs., what cooling would then take place?

CONSTRUCTION OF BOILERS.

5. *Boiler with Heaters.*

Example.—Determine the dimensions of a cylindrical boiler with hemispherical ends to supply 520 lbs. of steam per hour. Let the boiler be furnished with two heaters.

6. *Strength of Boilers.*

Example.—Find the proper thickness of plate iron for the foregoing boiler, on the supposition that the working pressure is to be 4 atmospheres.

THERMODYNAMICS.

7. Apply Poisson's law for the specific heat of gases to determine the work done by the expansion of a given quantity of air, gas or steam; and state what modification the formulæ would undergo for each of these fluids.

Example.—The inner diameter of a high pressure, double-acting, expansive steam engine is 18″; length of stroke is 40″; number of revolutions per min. 24; the steam gauge stands at 65 lbs; the steam is cut off at .4 of the stroke; what is the power of the engine, and how much steam is required per hour?

QUANTITY OF FUEL CONSUMED BY A STEAM ENGINE.

8. A low pressure, non-expansive steam engine has a cylinder 6′ long, and $2\frac{1}{2}$′ in diameter; number of revolutions per minute 18; temperature of the steam 104° C.; temperature in the condenser 35° C.; efficiency of the engine, 0.60. What is the power exerted on the

crank? How much steam is used per hour? How much feed water at 30° C., will be required to supply the boiler? How many units of heat per second will be required to produce this steam? Let the efficiency of the furnace be 0.75, that of the heating surface be 0.60 and suppose 1 lb. of coal to contain 7500 units of heat. How much coal is consumed per hour? How much per horse power per hour?

9. *Expansion slide Valve.*

Example.—The radius of the eccentric is 1.57″, the steam is to be cut off at $\frac{1}{4}$ of the stroke. Compute the breadth of the port in the expansion valve.

10. *Balancing Locomotives.*

Show how to compute the proper weights to balance the centrifugal force in a locomotive.

Example.—Show how to balance an inside cylinder engine of the following dimensions: Distance between the centres of the cylinders = 2′ 6″, distance between the wheels 4′ 7″. Weights of the moving parts; crank referred to the pin 93 lbs.; connecting rod 188 lbs.; piston and rod 174 lbs.; cross head 64 lbs. Distance of the centre of the counterpoises to be 3 times the length of the crank. Determine the weight and position of each counterpoise.

GRAPHICAL WORK: PROJECTS.

Projects for machines and motors are given when the students have been made acquainted with the doctrine of the strength of materials, so as to be able to find the dimensions of pieces to resist flexure, shearing, torsion, etc. They consist of original designs for machines, involving the determination of the strength, dimensions, and proper proportions of the several parts by calculation.

The programme of a project, given during the current year, is here inserted as an illustration of the kind of work accomplished.

PROJECT FOR A TRAVELLING CRANE TO BE USED IN THE CONSTRUCTION OF A STONE BRIDGE.

PART FIRST.

The load is to be moved along the bridge, across the bridge, and vertically.

For this purpose there should be established a line of railway, one rail being placed on each side of the service bridge; upon this track a car with four wheels is to run; the platform of this car should consist principally of two wrought iron hollow beams. Upon this car should be placed a second track, at right angles with the first and laid upon these beams. Upon this second track a second car should be placed carrying a crab engine furnished with a brake, a ratchet and detent.

The present project is divided into two parts. The first consists of a memoir and the sketches requisite for understanding the machine as a whole and in detail. In the memoir the arrangement of the parts should be clearly described, and the dimensions given to the principal pieces verified. Finally, the force necessary to produce each of these three motions is to be calculated considering the effect of friction. 35 lbs. should be the limit to the effort of a man turning a crank.

The traction of the car is two per cent. of the weight. The data are as follows:—

Maximum weight to be lifted	15,000 lbs.
Vertical distance " " "	.20 ft.
Width of the first track	.40 ft.

GRAPHICAL WORK: PART SECOND.

The students will make a general plan, an elevation, and a section; also, the details of the transmission of all the motions, the brake, the engaging and disengaging gear, and in fact every thing necessary for the complete comprehension and construction of the machine.

These drawings should be shaded in india ink, and the nature of the materials employed, should be shown by the conventional tints.

The following projects, requiring more or less original research have been done during the present year.

1. Project for an outward flow turbine to drive a cotton mill.
2. Project for a travelling crane to be employed in the construction of a stone bridge.
3. Report on the construction and efficiency of the compressing pumps used at the Mt. Cenis tunnel, for supplying compressed air to the boring machines, accompanied with elaborate drawings.

4. The computation for the construction and establishment of a packing press capable of exerting a pressure of 80 tons.

5. Project for a water wheel according to the system of Poncelet; to be used for driving a flour mill.

6. Project for a rolling mill driven by a steam engine.

7. Project for a parallel flow turbine system according to the system of Jonval, to furnish the power sufficient for a machine shop.

8. Project for a gas engine according to the system proposed by Mr. Brayton.

9. Report on the construction and efficiency of the compressing engine used at the Mt. Cenis tunnel for supplying compressed air to the drills with drawings of the engine and its details.

These projects comprise:—

1. The plans, elevations and sections of the machines.

2. The working drawings of the details.

3. A memoir containing the description and theory of the machines; the estimation of the resistances; the calculation of the strength and proper proportions of the parts, and the reasons for the particular dispositions adopted.

EXCURSIONS.

In aid of the practical studies of the School, the students have made a number of excursions, for the inspection and study of machines. The most recent are as follows:

Feb. 17. To Brayton's Gas Motor:—

The principles, the mode of action, with the details of the construction were explained by diagrams, and illustrated by the practical working of the machine. The analogy between this motor and the common caloric engine was carefully explained, together with the devices employed for substituting for ordinary gas, the vapors of the volatile hydro carbons.

The differences between this engine and those explosive engines of Lenoir and Hugon were pointed out, together with the novel and ingenious application of the principle of Bourdon's gauge for automatically regulating the pressure.

Feb. 24. To the Boston Gas Works to examine the practical working of Hugon's Gas Engine.

The mechanism of the valves and the construction of the interior of the machine were shown by diagrams; the quantity of gas consumed was observed, and the cost of running estimated. The effect of the introduction of a jet of water into the cylinder was exhibited by curves showing the changes in the manometric pressure.

March 2. To Houghton's Automatic Steam Pump. The apparatus was shown by a beautiful glass working model. The analogy between this and Savery's steam engine was pointed out, together with the improvements introduced which rendered it safe and automatic.

March 14. To the Navy Yard in Charlestown, to see the powerful machinery employed in bending timber, the invention of Mr. Griffith, together with the travelling cranes, hydraulic presses, the Corliss steam engine, boilers, feed water heating apparatus, etc.

March 30. To the works of the Iron and Steel Company at Nashua, N. H. Here the students had an opportunity of seeing a Semen's gas furnace, the Martin process for making steel, Armstrong's hydraulic cranes and accumulators for handling the ladles and ingots, the process of forging and finishing steel, and the rolling of large steel tires, requiring the use of heavy steam and hydraulic machinery. They also visited the Nashua Cotton Mills, where they saw a Boyden turbine of enormous power; also the works of the Nashua Lock Company.

April 27. To the Atlantic Works, in East Boston, to observe the practical working of Mr. Ellis's Binary Vapor Engine for economizing the heat of exhaust steam by using it to vaporize sulphide of carbon. The ingenious air condenser was noticed, also the precautions to prevent the leakage of the volatile fluid. The analogy and the difference between Mr. Ellis's engine and that of M. DuTrembley was pointed out. Visits were made to the pattern shop, forge, and machine shop.

In concluding this portion of the report the Professor in charge desires to express his obligations to the Superintendent of the Boston, Lowell and Nashua Railway, and to the Super-

intendents of the various establishments visited, for courtesies extended.

ADDITIONAL MODELS.

The following additional models have been received during the past year:—

A beautiful model of a warped helicoid with its tangent hyperbolic paraboloid.

A set of models illustrating the principles of perspective.

A set of models of right and oblique bridges, with their approaches and other accessory works.

Model of a furnace and fire grate.

Model of a French boiler.

Model of an endless screw motion.

Model of a face wheel and lantern gearing.

A highly finished model of the compound engines of the screw steamship Hecla, of the Cunard Steamship Line, presented by David MacIver, Esq., of Liverpool, England.

The following models were omitted in the report for last year: —

A new form of coupling, presented by Mr. S. P. Ruggles.

A new form of pulley, presented by Mr. N. M. Lowe, and called by him a universal pulley.

A silent feed motion used in sewing machines, presented by Mr. Charles L. Spencer.

A model of the metallic packing of a steam piston, presented by Mr. Horace McMurtrie.

Models of the peculiar mechanism of stem-winding watches, presented by Mr. J. H. Gerry.

Models of eccentric gearing, presented by Mr. S. P. Ruggles.

In conclusion, attention is called to the three-fold use of the models; first, in the drawing rooms as objects from which sketches and finished drawings are made; second, in the lecture

rooms, to illustrate the principles of machinery, and to exhibit to the eye what would otherwise require long and tedious explanations; and third, in the practical exercises in construction and design, which would be difficult, if not impossible, without them.

All of which is respectfully submitted,

WM. WATSON,

Professor of Mechanical Engineering,
Mass. Institute of Technology.

REPORT ON THE INSTRUCTION IN THE DEPARTMENT OF ENGLISH.

President J. D. Runkle, Sir : —

I beg leave to present the following Report of my doings in the department of English and History during the past school year.

The question of the best method of adjusting my instruction to the real wants of the students of the Institute, has been from the outset a very perplexing one. The imperfect preparation for the scientific studies of the course which the students bring with them lays a heavy pressure upon them in that direction; and, on the other hand, the deficiencies of too many of them in English studies require an attention to rudimentary drill, especially in Composition, which should properly have been completed before admission. A gradual but steady rise in the standard of qualifications for admission to our school, to correspond with the improvements which are making in the English and Scientific instruction given in our High Schools, will eventually remedy much of this difficulty. I have to report that I have been successful in securing a regular attendance and an interested attention to my lectures. I have nothing but praise for the conduct of the students, and am confident that good results have been attained beyond what can be exhibited by a formal

examination. Students just emancipated from the restraints of school, and just passing from boyhood into young manhood are in a peculiarly receptive condition of mind in regard to the moral, political, social and æsthetic questions which form the real subjects of instruction in History and Literature. They are beginning to think for themselves, and are looking forward to a new future, where they will have to act for themselves. It is a period when judicious oral instruction can be made of more value than either before or afterwards. Lecturing therefore forms a very legitimate method of instruction, and, where the student's brain is constantly taxed by a very large amount of hard mathematical and scientific study, so that the mental discipline must under any circumstances come mainly from the scientific side, lecturing must continue to hold an important place in the literary and historical departments; and, it is very observable that the mental training obtained through the instrumentality of the severe discipline of the former class of studies perceptibly increases the intelligent interest of the students in the latter.

But lectures, to be of any value, must be supplemented by some literary as well as scientific work on the part of the students; and as it would be wholly impossible for one teacher to give elaborate and distinct courses of instruction in Rhetoric, Logic and Criticism, and also in political and literary History, my aim has been to comprise as many different elements as I could in one or two courses, and to connect with them as much practice in writing as time permitted. The students of the classes of the first and second years have taken brief notes of lectures, and written them out in manuscript books, which have been regularly examined by my assistant, and all elementary errors in spelling, punctuation and style corrected. Elementary deficiencies are very general. I have taken the ground that while the Institute of Technology does not offer itself as a teacher of writing, spelling, punctuation and the rudiments of the art of composition, it will give all the incidental help it can to its students for the making up of such deficiencies in their

school education, but should refuse to give a degree or diploma to any student who, by the end of the four years, has not acquired, directly or indirectly, a satisfactory proficiency in them

I think that by devoting a larger share of time to drill in composition during the first year, that object can be satisfactorily attained. After the first year, I am anxious to carry out more fully the system of requiring a certain amount of prescribed collateral reading in connexion with the lectures on History and Literature, accompanied by oral or written analyses of the same, or even lectures to be given by the students themselves. In this way practice in composition may be clearly combined with the oral instruction, and the general interest will be increased through the students themselves taking a more active share in the work. But for the proper carrying out of such a plan, I greatly need better library accommodations, and a better supply of carefully selected books; not a miscellaneous collection on any and all topics, but exactly the books that contain the collateral reading I wish to require. I consider that one of the greatest services I can do my pupils is to teach them how to use books. Their knowledge of the contents of English Literature and of the character and relative value even of modern writers, as tested by examination, is surprisingly small.

My course of instruction for the past year has been as follows: —To the first year's class I have lectured once a week on the writers of the last century, devoting a good deal of time to elementary ideas on the study of Literature in general. Notes of these lessons have been written out by the class. The other weekly exercise has been devoted partly to Composition, partly to lessons on Language and General Grammar, with special reference to the history of the English language. A portion of this last instruction could be given hereafter to better advantage by the Professor of Modern Languages, in connexion with the instruction in German and French, if a professor should be appointed who has a competent knowledge of the science of Comparative Philology, leaving me more time for much-needed work in the details of practical composition.

With the second my lessons have been mainly confined to the history and literature of the Eighteenth century, with special reference to English History and the events of our Revolution. The class have taken notes. They have shown much interest, especially in the American portion of these lessons, and might have done a good deal of collateral reading without detriment to their severer studies, if books on American history had been immediately at hand in the reading-room.

To the third year's class I have given a detailed series of lessons on the U. S. Constitution, along with as much instruction on English constitutional history and the general principles of constitutional law as time and my own reading permitted. These have occupied one of the two weekly hours. The other has been devoted to the oral translation, with a running commentary, of Guizot's "Civilization en Europe," the students having the French text open before them. Their knowledge of French has been thereby somewhat improved, and it has been the best means I could devise of giving the class a general view of the outlines of modern history. These lessons can be made much more valuable by going more slowly over the book and requiring some collateral reading, and occasional oral or written translations from the students.

With the fourth year's class my attention has been mainly devoted to Political Economy and the Commercial and Economical aspects of History. Adopting the smallest and least controversial manual that I could find, I have made it the text for a series of readings and oral lessons, designed mainly to interest the class in the investigation of the various politico-economical subjects, which have so close a connexion with their professions and future occupations in life. No subjects belonging to the English department are more important, or have proved more interesting to the students than these; but in the more technical parts of Political Economy, the subjects of Currency, Banking, &c., I have to lament my own lack of practical knowledge; and I would respectfully suggest that a brief course of non-contro-

versial lectures on these topics, explanatory of the ordinary course of business, and given by a practical business man, would be very useful.

The only assistance of this kind which I have received this year has been a short, but excellent course of lectures, given to the classes of the third and fourth years together, by Hon. Emory Washburn, Bussey Professor of Law in the Harvard Law School, in which the students were much interested. I feel personally under great obligations to Ex-Gov. Washburn, for this assistance, given, at the cost to himself of a good deal of time and trouble; and thanks are due to him for the interest he has thus again practically shown in our institution.

In this connexion I will also mention our obligations to Hon. Charles Sumner for repeated gifts of valuable public documents.

As the result of the enlargement and reconstruction of the course on Science and Literature, I have had, during the second term a small extra class in English studies. From want of time, owing to the absence through illness of Prof. Howison, I have not been able to do anything very systematic with them. They adopted my proposal to study, as far as time allowed, in connexion with our two weekly meetings, the actual present condition, political, social and economical, of some of the leading nations of the world, as given in the most recent authorities; as E. G. Martin's Statesman's Year-Book, the writings and speeches of Grant Duff, the leading periodicals, &c. The experiment was sufficient to show how valuable and interesting such instruction might be made to young men who are looking forward to the active career of business men, manufacturers or merchants, and I trust that as our institution develops, more resources may be put at the command of the English department for perfecting it.

After this detail of my labours I hardly need say that they have been too varied and multifarious to allow of their being performed with proper thoroughness. I look forward with the greatest satisfaction to the prospect of sharing the work of this department with another teacher. With the aid of a Professor

of Modern Languages, if we shall be so fortunate as to obtain one, I shall hope to be able next year to confine myself to a narrower circle, and to be able to undertake with the students in Science and Literature more careful and detailed extra instruction in History and English Literature.

All which is respectfully submitted.

W. P. ATKINSON.

May 19, 1872.

REPORT OF THE DEPARTMENT OF PHYSICS.

To the President of the Institute:—

A somewhat detailed account of the course of instruction in the Physical Laboratory has been given in previous annual reports, and it remains substantially unchanged for students of the Third Year except by the introduction of many additional experiments. The present Report will therefore be confined to a description of the extension recently made by introducing the study of Physics into the Fourth Year. In the earlier part of the laboratory course a full description is given of each experiment, and the apparatus necessary for performing it is put in perfect order, so that the student can at once proceed. This, however, is very different from cases arising in actual practice. The engineer or chemist who wishes to undertake any original investigations must generally devise his own apparatus, make it, or at least superintend its construction, perform the necessary experiments, and finally, if the results are of value, prepare a report of them for publication. The subject is presented to the students of the Fourth Year in precisely this form. A problem in practical physics is suggested to them which they are expected to work out experimentally, and report the results. As examples the following extracts from a portion of these reports are appended, retaining as far as possible the student's own words. The illustrations are necessarily omitted, also the curves exhibit-

ing the results, and in most cases the tables are very much abridged. The actual amount of work done is therefore much greater than would appear from the perusal of the following pages. As this course has been on trial only during the past four months, great improvements are to be expected when experience has shown the kinds of experiments that can be most profitably performed by the student, but we believe that enough has already been done to show that results may be obtained, which shall be of great use to the student as a method of training, and at the same time possess considerable scientific value.

MECHANICS OF SOLIDS.

A number of pine rods as nearly alike as possible were provided and used by the students as units with which to form a variety of trusses. The following will serve as an example:

Report upon Experiments on a Queen-Post Truss and its component parts, by Messrs. C. S. Ward and B. E. Brewster.

Several series of experiments were made upon a number of beams supported at both ends, distance between supports being 66″. Weight applied in the centre, 6 lbs.

The deflection was measured by means of a millimetre scale pasted upon a strip of wood, and suspended in the middle of the beam. The beams used were 6′ long, and $\frac{1}{2}$″ square.

(In the original report a table is here inserted, showing measurements of scale-readings before and after the weight was applied, the deflection and permanent set. Five beams were used, and the measures repeated after turning them over. Deflections in cm. were as follows:— 7.85, 7.95, 9.15, 9.50, 7.95, 8.05, 10.30, 10.65, 7.45, 7.80).

Average Deflection, 8.86 cm. Average permanent set, .5 cm.

Another beam, No. 6, was similarly tested on its 4 sides to compare the relative strength. Deflections, 7.80, 8.00, 7.90,

7.85. Beam No. 6 was loaded as before with a wt. of 6 lbs. and readings taken at intervals of $\frac{1}{2}$ minute until deflection became constant. Results 12.90, 12.95, 13.05, 13.10, 13.15, 13.15, 13.15. The first reading was at the end of one minute. Curve No. 2, represents this increase of deflection.

Beam No. 5 was used for determining the deflection under a varying weight. Deflections from 0 to 8 lbs., 5.00, 6.30, 7.55, 8.85, 10.15, 11.50, 12.75, 14.05, 15.75. By examination we see that the changes in deflection were very constant, with the exception of the last, and in accordance with the law that the deflection is proportional to the weight. Curve No. 3 shows this result. Next, experiments were made to get the form of the deflected beam. For this purpose a constant weight of 8 pounds was applied in the middle, and a series of readings with and without the load was made at points 3″ apart. Length of beam as before, 66″. Deflections, 9.9, 9.85, 9.60, 9.80, 8.30, 7.35, 6.30, 5.10, 4.00, 2.65, 1.15. The deflections are shown in Curve No. 4.

A weight of 6 lbs. was then applied to the beam at different points taken at intervals of 3″ from 33″ to 15″, in order to determine the relative deflections, which were 12.75, 12.60, 12.30, 11.70, 10.80, 9.80, 8.70.

The breaking strength of the beams was then tested. Distance between knife-edges, 5′, weight applied in the centre. The tension on the beam at the moment of rupture was noted by means of a spring balance ; accuracy limited to $\frac{1}{4}$ of a pound. Breaking weight of beams Nos. 7 and 8, $17\frac{3}{4}$ and $18\frac{1}{2}$ lbs. respectively.

From beams similar to those already experimented upon, a queen-post truss was built of the dimensions shown in the figure. Length of truss, 60″. Height, 10″. Distance apart of queen-posts, 20″. Distance apart of two trusses forming sides of bridge, 12″. Beams bolted together with iron bolts $1\frac{1}{2}$″ long, $\frac{1}{4}$″ in diameter.

The combined trusses were first subjected to a load of 100 lbs. applied midway between the trusses, and distributed uniformly throughout the length. Readings were taken at 7 points of the roadway at distances from one end of 3, 10, 20, 30, 40, 50, 57 inches respectively, that is one three inches from each end, one ten inches from each end, one at bottom of each queen-post and one at centre. Deflections, .20, .50, .50, .60, .60, .35, .20. The deflection was greater at one end of the beam than at the other, because there was a split in it. Curve No. 6 represents the results.

A weight of 70 lbs. was then applied in the middle of the truss with the following results, the points being at same distances as before. Deflections, .18, .04, .41, .88, .53, .02, .18. Curve No. 7 was constructed from these data. By inspection of this curve it will be seen that the beam actually rose a little between the bottom of the queen-posts and the ends of the main beams, owing to the whole thrust acting in the centre.

Measurement of the strain on the queen-post The post was removed and a spring-balance substituted in its stead, the distance being kept constant with each succeeding additional weight by means of a rod with adjustable nut. Applying at the centre eight 10 lb. weights in succession the observed strains were as follows: — 2, $5\frac{1}{2}$, 8, 10, 12, $14\frac{1}{4}$, $16\frac{1}{2}$, $17\frac{3}{4}$. In curve No. 8, horizontal distances represent weights, and vertical distances strains, on the post.

Strain on Struts. Found by replacing one of them by a spring balance in a similar manner to that described in the preceding experiment. With weights of 0, 10, 20 and 30 lbs., the strains were $4\frac{1}{2}$, $10\frac{3}{4}$, $16\frac{1}{2}$, and $22\frac{1}{2}$ lbs. respectively. Curve No. 9 was constructed in a similar manner to No. 8.

Similar experiments were made by Messrs. Dodge and Sparrow, preparatory to building a model of a Howe truss.

They first tried different methods of connecting two beams

end to end, and measured the force required to separate them. To test the method of computing the strains on any part of a truss, a beam was fastened at one end to an upright, the other end being held by an oblique tie-rod. The strain on each of these was measured as before by inserting a spring balance and compensating screw. The strain was thus measured for each pound weight added to the end, up to 15 pounds, and compared with the theoretical strain. The deviations due to friction, error in the balance, &c., were very small.

They then constructed a complete Howe truss of length 64″, width 12″, and height 8″. The ties were made of brass rods, on which they cut screw threads and made nuts to fit them. The finished bridge was tested by applying a load at the centre, ten lbs. being added at time, with results as follows: —

Load,	10	20	30	40	50	60	70	80	90	100.
Flexure,	.50	.75	1.25	1.75	2.25	2.75	2.85	3.45	3.75	4.25.

It will be seen that the deflection was only about one-sixth of an inch for a load of one hundred pounds.

Comparing this result with the flexure of a single beam, we see that the stiffness of the latter is only about one three-hundredth of that of the truss, and the student by placing his hand first on one and then on the other, has a far more convincing proof of the value of the truss system, than he could attain by any amount of mere theoretical study. A very complete model of a suspension bridge was made by Messrs. Stafford and Shepard, using common iron chain for suspension. Its span was 8′, and deflection 8″. The roadway was hung by 15 suspension-rods on each side, and the change in position of each was measured with the load applied at a single point, and also when uniformly distributed.

Measurement of the Angular Deflection of Beams fixed at one end.
By Mr. C. F. Allen.

The apparatus for this experiment when ready for use was as follows: — I. The beam itself, whose section was $\frac{1}{2}$ inch square, and length about 30 inches, carried a scale extending over 20 inches of its length. The beam was firmly clamped at one end between two other beams of sufficient stiffness to prevent any bending action from being transmitted beyond the outer point of support, and at its end a wire was fastened from which weights could be suspended. II. A mirror of plate glass mounted so that it could easily be attached to the beam at any point. III. A telescope with cross-hairs, mounted upon a wooden stand placed 60 inches from the mirror, and carrying a vertical scale; the zero point of the scale and the line of collimation or axis of the telescope being in the same horizontal plane with each other and with some point of the mirror. IV. Weights of $\frac{1}{2}$, 1, 2, 2, 4, lbs. respectively.

Principle:—When the beam was unloaded, the 0 of the scale was reflected upon the cross-hairs of the telescope; when a weight was attached, the beam was bent, the plane of the mirror was deflected through the same angle as that point of the beam to which it was attached, and the line of collimation of the telescope moved through double this angle; so that the deflection shown on the scale (in inches) divided by 60 gives the tangent of twice the angle of deflection of the beam; therefore the angle is easily determined by observing the deflection on the scale.

The experiment was divided into three parts;

1. The length of beam remaining constant with the mirror placed at the outer end of the beam, the weights were varied.

2. The length of beam and weight remaining constant, the position of the mirror was varied.

3. The weight being constant and the mirror placed at the outer end of the beam, the length of the latter was varied.

1. The length of the beam in this case was 20 inches and the weights ½, 1, 1½ lbs., etc., adding ½ lb. each time up to 5½ lbs.; a second series of observations was then obtained by removing ½ lb. each time; this was repeated three times making in all a series of six observations, with the following results:

Weights.	*Mean Scale Deflection.*	*True Angles.*
.5	1.08	0° 31′
1	2.15	1° 02′
1.5	3.21	1° 32′
2	4.52	2° 09′
2.33	5.65	2° 41′
3	6.80	3° 14′
3.5	7.92	3° 46′
4	9.23	4° 22′
4.5	10.38	4° 54′
5	11.56	5° 27′
5.5	12.65	5° 57′

2. The length of beam in this case was as before, 20 inches, the weight 5 lbs., and the mirror was placed at the outer end. Moving the mirror successively through intervals of 2 inches, the scale was read each time when the beam was not weighted, and again when the weight was added, the difference being taken as the scale deflection.

The results are shown below:—

Distances from Fixed End.	*Scale Defl.*	*True Angles.*
20	11.41	5° 23′
18	11.30	5° 20′
16	11.10	5° 14′
14	10.62	5° 01′
12	9.89	4° 41′
10	8.98	4° 15′
8	7.93	3° 46′
6	6.71	3° 11′
4	5.14	2° 27′
2	3.49	1° 40′

3. The weight was 5 lbs., the mirror was placed at the outer end of the beam, and the length of beam was varied two inches at a time, with the following results: —

Length of Beam.	*Scale Defl.*	*True Angles.*
20	11.42	5° 23′
18	9.56	4° 32′
16	7.56	3° 35′
14	5.93	2° 49′
12	4.56	2° 10′
10	3.17	1° 31′
8	2.07	0° 59′
6	1.32	0° 38′
4	0.65	0° 19′
2	0.24	0° 57′

Accompanying this are sheets showing the curves according to Experiment and Theory for each of the above cases.

Apparatus for ruling lines with a Diamond. By Mr. C. F. Allen.

This consists merely of a beam, with a slot at one end to receive the handle of a common glazier's diamond, and revolving upon an axis at right angles to its length, this axis being supported at its ends on upright posts. The pressure under which the diamond marks is thus kept sensibly constant and may be regulated by weights hung on the beam. The line is ruled by drawing the glass under the diamond.

This apparatus gives excellent results, some lines being so fine as to be difficult of perception under the $\frac{1}{8}$ inch objective of a microscope.

HYDRAULICS.

Coefficients of Efflux. By Messrs. W. B. Dodge and W. E. Sparrow.

The object of this experiment was to find the coefficients of efflux for different orifices and under various heads.

In this case there were two vessels, one for the water to flow from, and the other for receiving it. Each one contained a hook gauge by which heights could be measured very accurately. The gauge consisted of a wire with a pointed hook at its lower end; the other end moving vertically over a scale graduated to inches and decimals of an inch.

We fill the vessel until the water is level with the lower edge of the orifice, and take a reading by means of the gauge. The water is then allowed to run into the vessel and reach such a height that it just begins to flow away by the waste pipe. From the reading taken at this point, subtract the former one together with the distance of the centre of gravity of the orifice from its lower edge, and we thus have the true head.

In order that we may know the amount of water that flows into the second vessel, it must be carefully calibrated. This was done by pouring in one tenth of a cubic foot of water, taking a reading, and so continuing until the vessel was full.

Having described the apparatus in a general way we now proceed to perform an experiment. We first insert an orifice, say a circular one. The water is allowed to flow through it running to waste through a large rubber hose till the supply of water is so regulated that the head becomes constant. Then determine its magnitude in the manner described above. At a given signal the hose is removed and the water allowed to flow into the second vessel; at the end of a given interval of time the rubber hose is replaced and the water again runs to waste. The difference between the readings of the gauge in the lower vessel before and after the experiment gives the amount of water that will flow through the orifice, with the given head, during the given interval of time.

For heads which are at least four times the height of the orifice, theory gives for the discharge, the area of the orifice multiplied by the velocity due to the height of the water above the centre of gravity of the orifice. By dividing the actual by the theoretical discharge we obtain the coefficient of efflux.

Different orifices were used under various heads, and the results are placed in tabular form below:—

Shape of Orifice.	Dimensions.	Area.	Head.	Time.	Discharge		Coefficient of Efflux
					Actual	Theoretical	
Square.	.5″ × .5″	.25″	14.51	2	.460	.724	.63
			14.64	2	.468	.768	.61
			14.62	2	.464	.767	.61
Rectangle.	height .25″ depth 1.00″	.25″	10.10	2	.516	.638	.81
			10.10	2	.518	.638	.81
			10.12	2	.541	.638	.85
Rectaugle.	height = 1.00″ depth = .25″	.25″	12.64	1	.575	.713	.81
			12.78	2	.570	.717	.79
			12.64	1	.575	.713	.81
Triangle.	base .55″ height .546″	.15″	14.85	3	.304	.465	.65
			14.97	3	.307	.466	.66
			14.83	4	.304	.464	.66
Circle.	diam. = .5″	.196″	14.53	2	.465	.613	.76*
			14.35	2	.382	.594	.65

The friction of water in pipes was also measured by several students, using a horizontal brass pipe to convey the water, with vertical glass tubes having scales attached to show the pressure at different points. This gave the friction under a velocity which was found by measuring the amount of water escaping per minute.

Buoyant effect of a column of heated air from a Bunser burner.
By Mr. C. K. Wead.

A metal plate 283 mm. in diameter was placed over the flame and hung to one arm of a balance, and the force required to counterpoise it measured by double weighing. With no flame the force was 428.65 grs., with full flame 1 metre below, 431.2, at distance .8 m. 431.26, at .6 m. 431.

Using the formula for winds, (Silliman) velocity in miles per hour = $14.25\sqrt{\text{pressure in lbs. per sq. ft.}}$

Hence velocity=1.53 miles per hour=2.24 ft. per second.

* Erroneous.

2d Experiment. A Casella's air meter was substituted for the plate.

Height above burner.	Full flame.		One half flame.	
	Mean Velocity.	Max. Velocity.	Mean Velocity.	Max. Velocity.
0.6	2.75	2.85	2.61	2.72
0.8	2.07	3.32	2.42	2.57
1.0	2.88	3.08	2.23	2.47
1.2	3.01	3.38	2.04	2.18
1.4	2.86	3.05	2.35	2.47
1.6	2.67	2.87	2.10	
1.8	2.48	2.85		
2.0	2.03	2.08		

The currents were easily diverted from a vertical direction, and so probably the maximum velocity is more correct than the mean.

OPTICS.

Law of Lenses. By Mr. C. K. Wead.

The focal length of the plano-convex lens A on the stand was found to be $23.93'' \pm .03$. In this experiment the formula $\frac{1}{F} = \frac{1}{f} + \frac{1}{f'}$ was used, and $f + f'$ taken equal to whole distance between conjugate foci, *i.e.*, no correction was made for thickness. The same lens was remeasured and focus computed allowing for thickness, that is, $f + f' + t =$ whole distance between conjugate foci; the formula used was

$$\frac{1}{F} = \frac{1}{f} + \frac{1}{f'} - \frac{t}{n}\left(\frac{r}{n-1} - \frac{1}{u}\right)^2$$

$t_A = .25''$, r_A (by spherometer) $= .12.64''$, $n = 1.53$. From this observation $F_A' = 23.62 \pm .02$ taking in all the terms.

$F_A' = 23.56 \pm .03$ omitting the third term.

In this case it makes a difference of $.31''$ in the final result whether the focus of refracted rays is measured from the first or second surface of the lens, and if taken from the second surface the correction for thickness $= .06''$. Similar measurements were made on a second lens, and on the two combined and the results compared with theory.

The focus of a Tolles $\frac{1}{4}''$ objective, 2d quality, was measured by the method of Prof. Cross (Journ. Frank. Inst., June, 1870). A spider line micrometer and $\frac{1}{1000}''$ stage, were used and both measured in turns of the same part of the screw of the dividing engine; there is therefore no absolute measure entering into the formula for focal length, except l the distance between object and image, which was taken with a steel mm. scale. The foci of the three lenses A, B and C, of the triplet, were measured singly and in combination with the following results:

Lenses.	*Focus.*	*l.*	*n.*
A B C	.2447	256	39.11
A B C	.2555	216	31.26(?)
B C	.4454	258	20.755
A	.3081	260	31.186
B	.5076	258.5	15.764
C	1.459	287	5.571

The relative distances of the lenses were then measured and gave for thickness of A, .066, of B, .101, of C, .124, space between A and B .090, between B and C .007; length of whole combination = .388. Computing focus of BC, we get .407 or .411, according as we do or do not consider the small uncertain distance between them. The formula is based on the supposition that the rays are parallel, which may account for the slight difference.

Photometric Experiments. By Mr. C. K. Wead.

The following observations were made with a photometer in which two images of a single flame are compared, thus eliminating all errors from the fluctuations of the light.

		Probable Error.	Absorbed.		Plates.	Probable Error.	Absorbed.		Plates.	Probable Error.	Absorbed.
1	none		0.0	15	none	.6	—	28	none	.5	—
2				16	1	.4	15.7	29	1	.5	11.5
3	*A*	.7	12.6	17	2	.6	24.8	30	2	1.0	17.9
4	*B*	.6	12.3	18	3	.9	35.5	31	3	.6	26.8
5	*C*	.6	37.8	19	4	.8	41.6	32	4	.6	36.2
6	*C*	.6	35.0	20	5	.7	48.0	33	5	.	38.9
7	*D*	.8	37.3	21	6	.3	52.8	34	6	.6	44.1
8	*D′*	.6	29.7	22	7	.3	57.7	35	7	1.4	47.6
9	none	.8	—	23	7′	.6	59.3	36	7′	.2	45.0
10	*A*	.8	12.8	24	3′	.2	32.5	37	4′	.5	31.4
11	none	.6	—	25	2′	.3	24.1	38	2′	.7	17.5
12	*B*	.6	7.8	26	1′	.3	14.9	39	1′	1.2	6.5
13	*E*	.7	15.4	27	none	.6	—	40	none	.7	
14											

Each of these observations is the mean of several. Nos. 1—14 were made with a candle, the others with a single-jet gas burner.

Plate A, double English; B, thick plate; C, single German ground, C, ground side to light, C′, polished side to light; D, Berkshire ground, D′, same with polished side to light; E, double German. The plates used in Experiments 15—27 were found not to be alike — some flint and others crown; they were mixed photographic glasses. The plates in Experiments 28—40 were thin unused photographic plates; No. 1 was always towards the light. Accented Nos. as (7′, 1′,) denote a repetition of the experiment.

More light is transmitted by ground glass, if the polished side is towards the light, (6—9.) A wet cotton cloth transmits 18.7 of the light incident perpendicularly on it; when dry the amount transmitted was too small to be measured by this apparatus.

The following observations were then made with a common Bunsen photometer to determine the candle power of a 5 ft. Argand burner when consuming various quantities of gas.

Consumption.	*Observed C. P.*	*Corrected for candle.*	*Probable Error.*
5.974	24.03	25.00	.24
4.848	15.12	16.50	.13
4.818	15.20	16.09	.11
4.965	15.60	16.25	.12
3.828	12.86	10.45?	.12
2.568	3.46	3.29	.07
1.488	.222	.255	.005
.420			

The first column gives the consumption of gas; the second the observed ratio of the two lights, being the mean of from four to seven observations; the third the candle power corrected for amount of wax burnt, and the fourth the probable error. In the last case the light was too feeble to be measured, probably less than .001 of a candle power.

Experiments like the above by members of the 3rd Year's Class gave the following results.

Messrs. Shailer & Harris.			*Messrs. Blaisdell & Jewett.*		
Consumption.	*Observed C. P.*	*Corrected C. P.*	*Consumption.*	*Observed C. P.*	*Corrected C. P.*
6.12	18.35	19.27	6.45	19.7	21.67
4.92	18.9	19.37	5.98	17.5	18.37
3.60	11.56	12.14	5.22	15.7	15.31
2.28	2.91	3.28	5.38	17.2	15.90
1.52	.37	.35	4.84	12.4	13.02
1.44	.027	.029	4.35	14.1	11.47
.35	.00	.00	4.55	12.75	14.80
			4.09	12.79	12.79
			3.69	9.71	9.22
			3.37	7.34	7.71
			3.07	6.94	6.24
			2.96	3.84	4.03
			2.77	3.68	3.68
			2.46	2.17	2.28
			2.26	1.32	1.45
			2.04	.84	1.00

For the practical application of these observations, see papers by Profs. Silliman and Stimpson on Farmer's Law, in the Amer. Journ. Sci., 1870.

To Find the Refractive Formula (that of Cauchy) for any Substance. By Mr. F. W. Very.

The substance must be in the form of a triangular prism which is obtained in the case of a liquid by pouring it into a glass vessel of this shape. In the case under consideration, the substance was a piece of very dense and highly refractive glass, made into a prism having an angle of about 60°.

The instrument used was an optical circle, carrying two telescopes, one stationary for the purpose of furnishing a parallel beam of light, the other moving around the axis of the graduated circle, and having two verniers by which the angle may be read. The prism being placed at the centre of the circle, the light is refracted and dispersed, and the spectrum is observed through the second telescope.

The operation is as follows. The refractive index of the prism is taken for several of the most prominent lines in the spectrum, whose wave-lengths are known. This is accomplished by measuring the angle of minimum deviation D for each line and the refracting angle A of the prism, when the index n may be calculated by the formula,

$$n = \frac{\sin \frac{A+D}{2}}{\sin \frac{A}{2}}$$

It is necessary to find the index for at least three lines, but to insure greater accuracy a number of others were taken. The results were compared by means of the graphical method, and a slight correction was made upon three measurements at some distance from each other in the series.

These three values of n were then substituted in the formula,

$$n = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} + \text{etc.},$$

in which all the terms in the second member after the first three may be neglected. By elimination, the values of the con-

stants A, B and C for the substance under examination were found. In this case, they were as follows: $A = 1.683473$, $B = 96.30$, $C = 446.67$.

Having obtained the formula of the prism, it may be used to find the wave length of any line whose index of refraction has been measured.

To measure A, the refracting angle of the prism, this angle is placed facing the collimator so that the parallel rays coming from the latter shall be reflected from both faces of the prism as shown in the figure. The angle between the directions of the reflected rays $= 2A$ is measured. These measurements gave $A = 60° 1' 7''$, $60° 1' 0''$, $60° 1' 41''$, or the mean $60° 1' 20''$. The observing telescope was first focussed on an object about 80 ft. off, the focus of the collimator was then brought into agreement, and neither was changed during the measurement.

The prism being then placed in position and set at the minimum of deviation for each line in turn, the deviation was measured.

Line.	*Deviation.*	n.	$\lambda \times 10^7$	$\frac{1}{\lambda^2} \times 10^{-10}$
Na	58° 6′ 45″	1.71499		
Li α	57° 13′ 15″	1.70692		
B	57° 5′ 37″	1.70576	6867	212.06
C	57° 21′ 45″	1.70813	6562	232.24
a	57° 39′ 0″	1.71081	6277	253.80
D	58° 6′ 37″	1.71495	5892	288.05
E	59° 7′ 52″	1.72404	5269	360.20
b	59° 17′ 52″	1.72551	5183	372.25
F	60° 4′ 7″	1.73226	4860	423.38
Ti	60° 38′ 0″	1.73716	4665	459.52
Fe	61° 38′ 0″	1.74573	4383	520.54
H	61° 49′ 7″	1.74730	4340	530.91
Fe	61° 53′ 22″	1.74790	4325	535.83
G	61° 56′ 45″	1.74838	4307	539.08
	61° 59′ 37″	1.74876	4300	540.83
Fe	62° 11′ 37″	1.75011	4271	548.20
Cu	62° 20′ 22″	1.75170	4226	559.94

Micro-photography. By Mr. C. S. Minot.

During the course of instruction in photography by Mr. Whipple, it occurred to me that some experiments in micro-photography would be interesting. I accordingly arranged an apparatus by which the tube and lenses of a microscope could be substituted for those of a photographic camera. A box was taken, the back was knocked out and a hole a little larger than the diameter of the tube of the microscope was bored in the front. This hole was lined with felt to make it light-tight. On the back was fitted a slide which carried the ground glass plate on which the image was focussed, and the plate-holder.

The first experiment was with an $1\frac{1}{2}$ inch objective of Smith and Beck, and a Tolles B eye-piece. The size of the image photographed was $2\frac{1}{4}$ inches. The exposure lasted 4 seconds, direct sunlight reflected from a plane mirror being used. See No. 1. Similarly a fly's tongue, No. 2, and a section of Echinus spine, mounted in balsam, No. 3, were photographed.

I next attempted to take *Arachnoidiscus Ehrenbergii* Bailey, using a Tolles 1st quality $\frac{1}{4}$ with a B eye-piece. After several failures, caused by the shaking of the table during the exposure of the plate, I was successful (see No. 4). The exposure was four minutes and forty seconds.

Other negatives were taken with a B eye-piece and various objectives (see Nos. 5, 6, and 7).

I made one trial with an extension camera in order to obtain greater enlargement. With this I took *Arachnoidiscus Ehrenbergii*, using no eye-piece. The focussing was not perfect, however, and at the intersections of the lines, a beaded appearance is quite sharp and distinct, and suggests a doubt as to the value of Dr. Pigott's views as to the structure of podura scales as seen by his so-called "wonderful" aplanatic searcher. This photograph is No. 8.

I had proposed to use monochromatic light but had no time. My intention was to use light passed through an ammoniacal

solution of cupric sulphate. The object in using blue light would be to avoid the difficulty of the objectives not being ground to the chemical focus.

The cost of the apparatus to take these photographs, when one is provided with a microscope and objective, and exclusive of what can easily be made, is only about $10 for what is needed to take negatives, and $5 or $6 more for the printing.

Saccharimetry. By Mr. F. A. Emmerton.

The delicacy of the instrument to be used was first tested by adjusting the eye-piece, so that the sensitive violet tint was obtained, and then taking four successive readings, at the point when the color was the same in both sides, using water only in the tube.

These readings were as follows:

—.9; —.9; —9; —5;

thus showing that the instrument is quite sensitive.

The 0 point was evidently .9 of a division too far to the left, consequently it was adjusted, by use of the screw attached to one of the prisms, so that the point when the colors on each side of the field were the same, was always 0.

A sugar solution was prepared of presumably pure sugar so that it contained 16.471 grs. to the 100 c.c.

It was allowed to stand in the chemical laboratory five or six days before use, corked up in a flask. In that time it had changed by fermentation, as is shown by the following results:

99.1; 98.8; 98.9.—Average 98.9 per cent.

If the solution had not changed the readings should have been 100.

Another standard sugar solution was used immediately after preparation and gave the following results:

100.0; 100.1; 99.8; 100.1; 100.—Average 100.00 per cent., showing the sugar to be quite pure.

The long tube belonging to the instrument and intended to

be used for solutions after inversion ought to be one tenth longer than the short tube, in order to compensate for the 10 c.c. of HCl added to every 100.00 sugar solution in the inversion.

Consequently with a normal sugar solution it ought to give readings one tenth more than the short tube. It was tested with the pure normal sugar solution with this result:

110.9; 110.9; 110.6; 110.9; 110.9 per ct.—Average 110.88.

Showing the tube to be not exactly one tenth longer than the short one.

The same solution was tried three days after in the short tube with these results:

98.6; 98.4; 98.3; 98.3; 98.7 — Average 98.46, showing how rapidly a sugar solution changes in strength even when corked up in cool weather.

In looking for statements about the relative rotating power of inverted and uninverted sugar solutions I found great discrepancy of statement, but concluded from a statement in Bolley that the amount of sugar which rotates to the right 100, rotates to the left at 35.7 at 15° C. I inverted the pure solution and got the following readings at 18° C.

—37.6; —37.3; —38.; —37.9; 37.2.—Average 37.6.

Subtracting .88 the error due to the length of the tube it gives 36.7 as the reading at 18° C. I could not find any tables giving the correction for temperature, but that correction whatever it is would bring the reading nearer still to 35.7.

A large number of electrical experiments were made by the class, including measurement of resistances, making coils, a Siemens' thermometer, magnetization by frictional electricity, and others, but they are omitted, believing that the above are sufficient to show the nature of the work done, both as regards quality and quantity.

All of which is respectfully submitted.

EDWARD C. PICKERING,

Thayer Professor of Physics.

Massachusetts Institute of Technology.

PRESIDENT'S REPORT

FOR THE

Year ending Sept. 30, 1873.

BOSTON:
PRESS OF A. A. KINGMAN,
1873.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

PRESIDENT'S REPORT

FOR THE

Year ending Sept. 30, 1873.

BOSTON:
PRESS OF A. A. KINGMAN.
1873.

PRESIDENT'S REPORT.

To the Corporation of the Institute: —

This report relates to the year ending Sept. 30, 1873, to correspond with the fiscal and school years as now established.

In my last report so much space was devoted to several of the departments, that it will only be necessary in this to indicate such changes as have taken place during the year.

Department of Chemistry. Professor Crafts' statement on pages 59 and 60 indicates the spirit and aim of the instruction, and alludes to such improvements as have been made in the Quantitative Laboratory to facilitate work.

The instruction in General Chemistry and Qualitative Analysis, given to students of the first and second years, has continued under the direction of Professor Nichols, and the system and thoroughness with which it has been conducted, leave nothing to be desired but ampler space. We have but one laboratory, accommodating about fifty students at a time, in which to do this work. While these classes were small, this laboratory answered the purpose fairly well; but since they have become so large, that each must be divided into two or more sections, its use has been largely increased, and an urgent need has been felt for larger and better ventilated laboratories.

Besides, it is found impossible at all times to prevent the odors from the laboratories from permeating other parts of the building. There is also a great want of proper rooms for storing glass-ware and chemicals, and laboratories for gas analysis and the various applications of chemistry.

The importance of a new building to accommodate this important department is daily becoming more apparent, not only for its own proper development, but also for the relief it will afford to other departments, which must for some time to come be accommodated in our present building.

At the last session of the Legislature, your application for a parcel of land on the Back Bay was successful, and it is certainly to be desired that such a building as we so much need may be erected thereon during the coming year.[1]

Department of Geology and Mining Engineering. The courses of instruction in this department were fully detailed in my last report. During the year the Geology has been in the

[1] An Act in addition to An Act incorporating the Massachusetts Institute of Technology.

Be it enacted by the Senate and House of Representatives, in General Court assembled, and by the authority of the same, as follows:

SECTION 1. Perpetual right is granted to the Massachusetts Institute of Technology to hold, occupy and control free of rent or charge by the Commonwealth, for the uses and purposes of said Institute, a parcel of land situated in that part of Boston called the Back Bay, and described as follows: A lot in the form of a trapezoid lying at the intersection of Boylston street and Huntington Avenue, bounded by said street and avenue, and on the west by abutting land, as laid down on the selling plan of the Commissioners on Public Lands, and containing thirteen thousand one hundred and ninety-four square feet; said lot to be subject to the limitations and stipulations relative to lands of the Commonwealth on the south side of Boylston street, and to be reserved from sale forever.

SECTION 2. The right hereby granted to said Institute shall be held subject to the same stipulations in relation to membership, the reception of pupils, the erection of a building, and the care of the lot, as are created and established by the several acts relating to said Institute.

SECTION 3. In case said Institute appropriates said lot of land to any purpose or use foreign to its legitimate objects, then the Commonwealth, after due notice given, may enter upon said lot and take possession thereof, and the right of the said Institute to the use, occupation and control of said lot, shall thereupon cease.

SECTION 4. This act shall take effect upon its passage.

April 8, 1873.

Approved.

W. B. WASHBURN.

able hands of Professor Hunt, the value of whose instruction has been much abridged by the want of proper space for reinforcing the lectures by the corresponding laboratory work.

The department has also gained largely in the more complete equipment of the Mining and Metallurgical laboratories, which is due almost entirely to the zeal, energy, and excellent practical judgment of Professor Richards, to whose interesting report I respectfully ask your attention. We are indebted to Mr. Schubert for the drawings, and to another friend for the engraving of the cuts representing these Laboratories.

As part of the work of the department, I include the excursion made during the vacation just closed. At my request Professor Ordway has written a full account which I submit for your information. Excursions so systematically and ably conducted as this one, are of great advantage, not only to professors and students, but also, indirectly at least, to the industries to which they relate; and I heartily approve of Professor Ordway's suggestion, that such excursions should be annual and part of the recognized work of the school, and that some way may be found to aid those to whom the incidental expense may be burdensome.

It is only just to say that all of the excursions of past years would have been impossible had it not been for the ready and generous aid given us by railroads all over the country.

Department of Physics. Last year's report on this department related to the instruction given during the third and fourth years in the Rogers Laboratory of Physics. No important change in the method of instruction has been found necessary. The laboratory has gained somewhat in apparatus, but mainly in such things as have been designed and made in the building. You are respectfully referred to the report of Prof. Cross on the instruction in physics in the first and second years of the course. The publication of Professor Pickering's Laboratory Manual, and the printing of Professor Cross' notes, have greatly aided in the instruction.

Your thanks are due to Mr. J. C. Hoadley for a valuable collection of acoustic apparatus, a list of which you will find on pages 71 and 72. The urgent need of the department is a fund, the income of which can be used to keep the apparatus up to the latest date in all branches of the subject.

Industrial Design. In my last report I had the pleasure of announcing the intention of the Trustee of the Lowell Institute to establish in this Institute a course of instruction in Industrial Design. The vote establishing the department was passed Sept. 11, 1872, and the following circular was issued shortly after, which is inserted here as part of the history of the department.

LOWELL COURSE OF INDUSTRIAL ART.

The Trustee of the Lowell Institute having made provision for a special course of free Instruction in Practical Design for Manufactures, open to pupils of both sexes, students will be received at the beginning of the school year in October, to whom will be taught the art of making patterns for Prints, Delaines, Silks, Paper-Hangings, Carpets, Oil-Cloths, etc.

The Course will embrace: —

1. *Original Design, or Composition of Patterns:* —

This comprises the making of original sketches for patterns, in light and shade, flat or shaded tints and in outline.

In connection with this work instruction will be given in the harmony of colors and in proportion.

2. *Secondary Design, or Variation of Patterns:* —

This comprises the alteration and adapting of patterns, either as to form, color, or the number of colors employed, simplifying them or making them more elaborate, and adapting them to different fabrics.

In connection with this work the study of the recognized styles will be taken up, and attention given to the peculiar requirements of various markets.

3. *The Making of Working Drawings:* —

Under this head is comprised the working out of sketches and designs, and putting them into the form and scale required by the manufacturer. Practice will be given in the method of adjusting patterns for printed goods to the size of the blocks or rollers employed, and in drawing out the patterns for carpets and other woven fabrics upon paper whose surface is divided into small squares, each representing a "pick" or thread.

4. *Technical Manipulations:* —

This comprises instruction in the use of instruments and colors, specially adapted to pattern drawing; also exercises in enlarging, reducing and copying patterns.

The class will be arranged in four divisions, corresponding to these four kinds of work. The student, on joining the class after passing the prescribed examination, will enter the fourth division and will be advanced to the third, and to the second, and so on to the practice of original design as rapidly as his proficiency permits. The more advanced students will have the assistance of the lower divisions in the drawing out of their designs.

Instruction will be given personally to each student over his work, with occasional general exercises.

Drawing from Memory. The designer needs to be familiar with the objects and forms in use in designing, so as to be able to reproduce without a copy the details of ornament, the appearance and texture of fabrics and of natural materials, and the forms and colors of leaves and flowers, which are the chief basis of decorative art. To this end special exercises in drawing and coloring from memory will constantly be given out.

Manufacturing Processes. A competent knowledge of the machinery and other appliances in use, and some familiarity with their working, is important to the designer. Without it his designs, however skilful, will be worthless. With a view to the acquisition of such knowledge the various processes of printing and weaving will be explained to the students, as may from time to time be needful, and excursions made to manufacturing establishments in the neighborhood where these operations may be witnessed upon a large scale.

It is intended that this course of study shall be thorough and practical, so that students may here qualify themselves to become draughtsmen or designers in manufacturing establishments, as their proficiency and capacity may determine.

The class will be provided with samples of textile fabrics, paper hangings, carpets and oil-cloths, both American and European, and with specimens of Oriental and other woven and printed fabrics selected for their artistic value and as illustrating the application of design to manufactures. To these will be added some examples of drawings made by pupils in foreign schools of design

The class will be open to pupils of both sexes and will be under the personal direction of Mr. Charles Kastner, for fourteen years designer at the Pacific Mills, formerly Director of the Atelier Lebert in Paris, and nephew and pupil of M. Jean Baptiste Lebert, *Dessinateur*, of Mulhouse in Alsace.

It will open on Monday, October 7th, and will continue daily, except Sundays and holidays, until the end of May. Hours from nine till one, and from two till five o'clock, except Saturday afternoons. Regular and

punctual attendance will be strictly required. Students will supply their own instruments and materials.

Requirements of Admission: —

Applicants for admission to the Lowell Course of Industrial Art will be required to bring specimens of their work, exhibiting a thorough acquaintance with Free-hand Drawing, and some familiarity with the use of mathematical instruments, and of the brush in laying flat and graduated tints with India-ink and with color; all of which is an indispensable preliminary to the study of designing.

Entrance examinations will be held on the 4th and 5th of October at 9 A. M., at the Massachusetts Institute of Technology, Boylston St., Boston. Applicants will bring as many samples of their work as is convenient.

For copies of this circular address

SAMUEL KNEELAND,
Secretary.

Mass. Inst. of Tech., Boylston St., Boston,
Sept. 20, 1872.

A reference to Mr. Kastner's report, on page 66, will show what has been accomplished during the year in this department. It is my pleasure, as well as duty, to testify to the zeal and faithfulness of both teacher and pupils, and to express my entire satisfaction with the results. In judging of the quality of the work, it should also be remembered how little of proper preparation most, if not all the pupils, possessed at the beginning of the year. The fact that nearly all of them have returned, is the best evidence of their interest in the work.

It is important to the highest success of this department, that the pupils should remain until they are thoroughly qualified to enter upon their profession, and to this end I earnestly recommend that a course of not less than three years be marked out, and that to those pupils who successfully accomplish it, shall be awarded a diploma by the Corporation.

It is proper in this connection to state that all the expenses of the department for the year, in the purchase of samples of textile fabrics for illustrating the instruction, have been paid out of a contribution by James L. Little & Co., of two hundred dollars, and that Mr. John A. Lowell has placed a like sum at our disposal for the coming year.

Department of Military Science and Tactics. During the year we have availed ourselves of the Act of Congress, authorizing the detail of an officer of the army to give this instruction. Lieut. Zalinski entered upon this duty only in March last, but devoted himself so zealously and efficiently to the work for the small remaining part of the session that commendable progress was made towards putting the department in a satisfactory condition. Considering all the circumstances, enough was done to satisfy all reasonable expectations for the future, and particularly to show that if the discipline of the department is properly supported, it may be made a valuable element in the *morale* of the school. Lieut. Zalinski's suggestion of the need of a proper hall for the use of the department is fully endorsed; also the use which may be made of it for systematic gymnastic exercise. The adoption of a more serviceable and tasteful uniform is earnestly recommended.

Department of Mechanical Engineering. In June last Prof. Watson resigned the professorship of Mechanical Engineering and Mr. Channing Whitaker, a graduate in this department in the class of 1869, has been chosen to fill the vacancy.

It is important that this occasion should be improved in making such changes in the methods and facilities as the experience of the past seems to indicate. To this end I have asked Prof. Whitaker to suggest such a laboratory as will best aid in the education of mechanical engineers; and particularly in the solution of those experimental problems which lie at the foundation of all safe theory or practice. The delay in the issue of this report, also enables him to briefly indicate the plan of instruction which has been entered upon. Your attention is asked to his report, with the earnest wish that you will authorize the establishment of this laboratory at as early a day as possible.

Department of Architecture. Although this department was among the first established in the Institute, and was classed

with the engineering departments in the applications of the higher mathematics to Construction, it was hardly to be expected that it would at once take rank with these in the public demand and appreciation. In the first place, there were in this country neither written nor traditional precedents to serve as guides in the instruction, nor were there any suitable collections for illustration. On this account, Prof. Ware's first duty was to spend the better part of two years abroad, in examining the systems of architectural instruction, and in making the nucleus of the collections which have since served so efficiently in stimulating and promoting the work of the department. At first the department seemed to attract only those students who had, or fancied they had, some taste for art, and judged this field the one most likely to gratify the taste, and at the same time yield a reasonable prospect of support. But these students were seldom prepared by early and suitable mathematical training to take the engineering side of the course. They remained a longer or shorter time, pursuing such portions of the course as they were qualified to take, gaining more or less, in proportion to time and effort expended, but failing to reap the full benefit of the course in any particular or important sense.

We are happy to say that this early and not entirely satisfactory phase of the department, is gradually, but surely, passing away. Regular students of thorough preparation and recognized ability, are beginning to enroll themselves, and the class of 1873 is the first to represent the department among its graduates.

Each year is adding something to the appliances, but more in experience, and in improving the details of the instruction. The selection of concrete examples of immediate interest, which have not only stimulated the invention, but the industry, of the pupils, has been a marked feature of the past year.

Department of Descriptive Geometry, Stereotomy and Drawing. The subjects embraced in this department, although clearly allied, were formerly distributed, and the instruction lacked unity, and the proper coördination.

Professor Warren's report shows the order in which the several subjects are now given, but further experience is necessary to show whether the amount of graphical work required may not be somewhat diminished without serious detriment to the course. This will certainly be possible when the elements of mechanical and free-hand drawing can be required for admission, a time not far distant, so far as the State of Massachusetts is concerned.

Five small rooms have been put upon the drawing-room floor, which are used as offices for those Instructors who are mainly employed in this and the mathematical departments, to make them more accessible to those students who wish special assistance, and to aid in maintaining proper order.

Department of Civil and Topographical Engineering. The instruction in this department continues to maintain the same high character which has distinguished it from the first. Rankine's Civil Engineering is used as the basis of the theoretical instruction, and the corresponding field work is all that could be desired, both in method and thoroughness. A few large and somewhat expensive instruments are still needed, and also a few additional models of American bridges. These bridge models I hope we shall soon be able to make in our own building under the direction of the department. Last year's report was issued too early to include more than a reference to the excursion of 1872, under the direction of Professor Henck, whose brief report is included among those of the present year.

Departments of English and History, and of Logic and the Philosophy of Science. The reports of these two departments are so full, both as to the ground gone over and the methods of instruction, as to require no further remark on these points. There is, however, an important relation which these departments bear to the work of the school to which reference should here be made.

It is becoming more evident as time passes, and the profes-

sional work of the higher years is broadened and intensified by increased laboratory facilities, and by more special attention to the practical applications, that these departments can hope to do but little, if any more, than hold their present ground in the professional courses. All we can do for these courses is, by gradually raising the standard of admission, to gain more time for these subjects in the earlier years.

But there is another work of growing importance which these departments, with others, are called upon to perform in the school, and that is the work of a general as distinguished from a technical or professional education. The germ of such an education now exists in our science and literature course, and this course is gradually assuming a more marked character; but only in this, that having a less definite and specific aim than the professional courses, the ends can be accomplished by a more diversified range of subjects. Instead, therefore, of but one general course, several might be laid down, each equally fixed and equally valuable for the end in view; or, what would probably better accomplish the same end, we might graduate students in a larger number of departments, and thus secure a greater variety in the courses, and a better adaptation to the wants of particular students.

But these are suggestions which, if of any value, will in time be worked out by the Faculty of the school, and presented for your consideration.

The year has been one of marked progress in our educational work, and I close this report by thanking every member of the Corps of Instruction for the able and faithful service he has rendered in securing this satisfactory result.

Respectfully submitted,

J. D. RUNKLE.

SECRETARY'S REPORT: 1872–73.

In conformity with article 16, section 4, of the By-Laws of the Corporation, I herewith present the Annual Report of the Transactions and condition of the Institute for the eleventh year, 1872–1873.

There have been held during the year thirteen meetings of the Society of Arts; these have not been as well attended as usual, on account of the derangement of the business of many of the members by the fire of November last, as well as the prevalence of a dreaded epidemic, and the uncommon severity of the winter.

Dec. 11, 1872. Mr. John A. Coleman read a paper on the Application of Mill Heating and Fire Protection to the Warehouse System.

Dec. 12. Mr. Ernest Edwards made a communication, illustrated by many specimens, some executed at the meeting, on "Photography in the Printing Press," or the Heliotype Process.

Dec. 26. Mr. Wm. B. Whiting read a paper on Warehouse Construction, with special reference to protection against fire.

Jan. 9, 1873. Mr. E. H. Hewins continued the subject of the proper construction of fire-proof buildings, and of the best way to extinguish fires in the quickest and least destructive manner.

Jan. 23. Prof. W. A. Rogers, of Cambridge, exhibited and explained a machine of his own invention, for determining personal equation, or the interval which elapses between an event and its perception by an observer.

Mr. Crandall exhibited working models of machines, invented by himself, for simplifying and expediting some of the processes in the manufacture of pianos.

Prof. Pickering described a new Difference Engine, or Tabulating Machine, the invention of Mr. George B. Grant, of Cambridge, comparing it with the celebrated Difference Engine proposed by Sir Charles Babbage some fifty years ago.

Feb. 13. Mr. A. Tacchella exhibited a working model of his combined fire ladder and escape, and hose elevator.

Mr. S. P. Sharples then addressed the Society on the subject of the disposal of slaughter-house waste and dead animals by means of chemical processes, which convert them into various non-offensive compounds of great value in the industrial arts.

Feb. 27. Mr. McMurtrie read a paper, illustrated by drawings on the blackboard, and by an extensive series of specimens, on the Tilghman process for engraving and cutting glass, stone, etc., by the use of a sand blast.

March 13. Mr. Edmund H. Hewins made a communication, illustrated by diagrams and drawings, on the Gilbert Elevated Street Railway of New York City.

Mr. Henry A. Page explained his system of suspended street cars, by which many of the inconveniences and expenses of the ordinary horse-railroad may be avoided.

March 27. The business of the meeting was the report of a Committee appointed to consider the best method of securing a greater interest in, and fuller attendance at, the meetings of the Society.

April 10. Mr. C. Millard made a communication on the Diamond-Saw Quarrying Machine, adapted to all kinds of rock cutting and dressing, illustrated by a carefully made sketch on the blackboard of nearly the size of the machine. What the

saw does for wood, it is claimed that this machine will do for stone.

April 24. Col. Jacob J. Storer addressed the Society on the best means of disposing of the waste of slaughter-houses and other animal refuse of large cities.

May 8. Mr. J. R. Robinson made a communication on the cause of the explosion of steam boilers, analyzing several cases which he had been called upon to examine.

May 22. Mr. H. P. Langley exhibited a new form of grate bar, by which ashes and light clinkers may be removed without opening the fire door.

Mr. Grosvenor exhibited in operation a very simple and effectual form of steam pump, with no movable parts except three or four automatically moving ball valves.

Mr. McMurtrie exhibited in operation, and explained by diagrams, Nye's Automatic Steam Vacuum Pump, now in use in this city for raising salt water.

There have been elected during the year 9 associate members, the list now comprising 336 members. One life member and 4 associates have died during the year, viz., Messrs. Savage, Dexter, Frothingham, Lynch and Sears. Nine have resigned during the year.

The School of Industrial Science has had a very satisfactory attendance, 375 students having enrolled themselves, viz.: Resident Graduates, 5; Regular Students of 4th Year, 32; of 3d, 27; of 2d, 61; of 1st, 115. Students not Candidates for a degree and Special Students, 4th Year, 24; 3d, 42; 2d, 31; 1st, 16. Students in Practical Design, of whom 13 are females, 22; total 375, or 111 more than last year; of these nearly five-sixths are from Massachusetts, principally from Boston and vicinity; 25 others are from New England, viz., from Maine, 5; Vermont, 4; New Hampshire, 7; Rhode Island, 6; Connecticut, 3; from other States there are, from New York, 9; Pennsylvania, 7; Ohio, 14; Illinois, 7; Kentucky, 3; Minnesota, 3; Indiana, 2; California, 2; Kansas, Delaware, Wisconsin and

Iowa, 1 each; from foreign countries, the Azores and Teneriffe, 3; Japan, 2; Sandwich Islands, 1; and British Provinces, 1.

Thirty-three professors and teachers have been connected with the school, and several advanced students have rendered assistance in drawing and surveying. The fees from students will reach $47,000, about $10,000 more than last year, and considerably more than the estimate of the Treasurer in May last.

The School of Design, under the auspices of Mr. Lowell, has proved a great success, and bids fair to be one of the most important aids to the industrial arts.

The Lowell courses this year have been as follows: 18 lectures on Descriptive Geometry, commencing Nov. 11, by Prof. Lanza; 18 lectures on Systematized French Pronunciation, French Conjugation and Idiomatic French, by Instructor Lévy, Nov. 11; 18 lessons in Machine Drawing, by Instructor Schubert, Nov. 12; 10 lectures on the Laws of Life and Health, by Prof. Kneeland, Nov. 12; 10 lectures on Modern History, by Prof. Atkinson, Nov. 13; 18 lectures by Prof. Hunt, on Chemical and Physical Geology, Nov. 29; 18 lectures on Experimental Mechanics, by Prof. Cross, Dec. 16; 10 lectures on Logic, by Prof. Howison, Jan. 22; 18 lectures on Translation of Lessing's Nathan the Wise, by Instructor Krauss, Jan. 20.

The same causes operated, as in the case of the Society of Arts, to render these courses less well attended than usual.

The Corporation have held eight meetings during the year, including the one of to-day, May 14th.

At the meeting of June 13, 1872, it was voted to establish advanced courses of study, and to change the title of the Degree conferred by the Institute to that of Bachelor of Science.

Sept. 11, 1872. Voted to establish the "Lowell School of Industrial Art," Mr. Lowell having offered to pay the salary of the head of said school.

Dec. 11. Solid Geometry and the rudiments of French, were added to the requirements for admission, and the fees were raised to $200 per annum. Mr. Charles P. Otis was

appointed Professor of Modern Languages, and the detail of Lieut. Zalinski, U. S. A., as Military Instructor, was requested from the War Department. It was also voted that the financial year of the Institute begin and end on the 1st of October in each year. The use of the large hall was granted to Trinity Church as a place of worship.

Dec. 27. A Committee was appointed to petition the Legislature for a piece of land between Huntington Avenue and Boylston St., for a Chemical Laboratory.

Feb. 12, 1873. The Degree of Bachelor of Science was conferred on eleven graduates of the Institute.

April 9. A letter was read from the Governor's Secretary, stating that the land asked for had been granted. At the same meeting Mr. Bowditch read a letter from an unknown friend of the Institute, giving the sum of $25,000, to be devoted to the payment of salaries.

A Committee was appointed to obtain plans for the new building, and also one to devise means for raising the money for its erection.

SAMUEL KNEELAND, *Sec.*

REPORT OF THE WORK IN LOGIC AND THE PHILOSOPHY OF SCIENCE.

To the President of the Massachusetts Institute of Technology.

I have the honor to present the subjoined account of what has been done in this, the first year of my duties as Professor of Logic and the Philosophy of Science, and of what I shall aim to accomplish in the future.

On the opening of my work in October, 1872, it became at once manifest that, under the existing arrangement of the courses of study in the several departments of the Institute, sufficient time for preparing my subjects was absolutely beyond the control of the great majority of the students in the two upper classes. After careful consultation, I asked and obtained the warrant of the Faculty to adjust my plans of instruction to the temporary exigencies of the general work by confining all preparation, on the part of the students of the then Third and Fourth Years to my actual hours of lecture, and by reducing the scale of work, both in amount and in minuteness, to correspond with this change. I mention the foregoing facts, to account for what might otherwise seem the small amount of instruction attempted this year in the Third and Fourth Classes. The actual work in these has been as follows: —

I. In the Fourth Year, so much, and only so much, of the Theory of Induction has been given, as seemed absolutely indispensable for a foundation of the Philosophy of Science. This

has included a pretty thorough discussion of the conception of Induction as a mental process, of the processes subsidiary to it—Observation and Experiment, Classification, Nomenclature and Terminology, and Hypothesis — and, finally and most especially, of the nature, conditions, and canons of the Five Scientific Methods — those of Agreement, of Difference, of Double Agreement, of Concomitant Variation, and of Residues. The method of instruction has consisted in the careful reading with the class of Fowler's text,[1] in the explanation, illustration and expansion of the same, so far as required and as permitted by the allotted time (two hours a week for the first half of the year), and in the careful and thorough criticism of the doctrines advanced by the author, or quoted by him. Free questioning on the part of the class has been encouraged, and oral examinations have been conducted from lecture to lecture, as the occasion seemed to require; these have been supplemented by one or two written ones. The precise objects aimed at have been (1.) to furnish each student with such a clear comprehension of the process of Induction, and of its conditions, as would render him distinctly conscious of his mental steps in any scientific investigation which he might be called to conduct; and (2.) to teach by a thorough example the true method of reading and mastering a subject, as presented by a scientific writer.

At the final examination for degrees, held May 27, 1873, the following paper was presented to the class. It will enable one to form a very fair judgment upon the nature of the work attempted, as it is similar in character to the paper used at the semi-annual examination, though somewhat more difficult.

[Examination of the Fourth Year's Class in Logic, May 27, 1873.]

Examine carefully the following investigation, and write down the *precise* proposition sought to be established by it. Then state by which of the Four Experimental Methods the reasoning is governed, and write out an analysis of the investigation, so as to show exactly

[1] A *Treatise on Inductive Logic*, by Thomas Fowler, M. A., Oxford: at the Clarendon Press.

the points in which it agrees with the Essential Elements of the Canon corresponding to the Method.

"The north-east wind is known to be specially injurious to a great many persons. Let the inquiry be — What circumstance or quality is this owing to? By a mental analysis we can distinguish various qualities in winds — the degree of violence, the temperature, the humidity or dryness, the electricity, and the quantity of ozone. We then refer to the actual instances, to see if some one mode of any of these qualities uniformly accompanies this particular wind.

"Now, we find that, as regards *violence*, easterly winds are generally feeble and steady, but on particular occasions are stormy; hence we cannot attribute their noxiousness to the intensity of the current.

"Again, while often *cold*, they are sometimes comparatively *warm;* and although they are more disagreeable when cold, yet they do not lose their injurious character by being raised in temperature; so that the bad feature is not coldness.

"Neither is there one uniform degree of *moisture;* they are sometimes wet, and sometimes dry.

"Again, as to *electricity*, there is no constant electric charge connected with them, either positive or negative, feeble or intense; the electric tension of the atmosphere generally rises as the temperature falls.

"Farther, as respects *ozone*, they have undoubtedly less of this element than the south-west winds; yet an easterly wind at the seashore has more ozone than a westerly wind in the heart of a town.

"It would thus appear that the depressing effect cannot be assigned to any one of these five circumstances. When, however, we investigate closely the conditions of the north-easterly current, we find that it blows from the pole to the equator, and is for several thousand miles close upon the ground; whereas, the south-west wind, coming from the equator, descends upon us from a height. Now, in the course of this long contact with the ground, a great number of impure elements — gaseous effluvia, fine dust, microscopic germs, etc. — may be caught up and remain suspended in the lower stratum breathed by us. On this point alone, so far as we can at present discover, is the coincidence of all the instances of the east wind constant and uniform.

"If, then, our elimination be supposed complete, there is a proof that the deleterious influence is due to the circumstance last named."

Does the investigation satisfy the conditions of the Canon, and is the conclusion valid?

The responses of the class to this paper were highly satisfactory, almost without exception; as indeed they also were, in almost as high a degree, to the examinations previously conducted.

Nothing more in Logic or Philosophy has been attempted with this class, and it is therefore necessary to show how my time has been spent with them during the second half of the year. It was my desire to advance somewhat into the detail of the Philosophy of the Sciences, especially into that of Mathematics; but the Government having expressed a strong desire that the subject of Political Economy should be presented, at least in clear outline, and having requested me to step aside from the strict line of my labors long enough to perform the duty of giving the necessary instruction in that subject, I complied, but found it impracticable to accomplish anything valuable without occupying all that remained of my time with this class. The time since February, 1873, has accordingly been given to Political Economy. I have read with the class, in a manner similar to that pursued in the case of Fowler's *Logic*, Mr. Walker's treatise on the *Science of Wealth*, taking pains to present the points in which other leading writers differ from him, and to develop with especial clearness both sides of the great dispute between Protection and Free Trade. The class have shown great interest in the subject, and at the final examination, held May 12, 1873, not a single member was conditioned, while the great majority passed at a very high grade. The paper set is subjoined, and I cannot at this point forbear remarking upon the general excellence of the English writing in the papers presented by the class; it was terse, clear, and in almost every case, noticeably free from defects of every kind.

[Examination of the Fourth Year's Class in Political Economy, May 12, 1873.]

1. Show how the action of the three elements — Desire, Labor, and Wealth — renders the realm of Political Economy an ever-expanding one, and how it is that they render Political Economy a *positive* science.

2. Define *Wealth*, in its strict, scientific sense.

3. Define *Value*, show what are its two essential conditions, and point out the ambiguity, in the ordinary use of the term, which must be carefully avoided in Economic Science.

4. Define *Labor*, and prove that the service of slaves, or any other involuntary work, is not labor in the economic sense.

5. Define *Capital*, and show why the distinction sometimes made between "active" and "idle," or "productive" and "unproductive" capital, is futile.

6. What are the three principal modes of Production, and what the three conditions of its highest success?

7. State some of the principal advantages of Division of Labor, show its limitations, and point out some of its evil tendencies, which need to be counteracted.

8. What is the conclusive argument in favor of Free Trade, from a strictly economic, or merely *monetary* point of view; and what is the equally conclusive argument in favor of Protection, as a policy sometimes absolutely necessary, though temporary?

9. What are the essential conditions of a good Currency? Show that neither a Credit Currency nor a Mixed Currency can satisfy these conditions, and why. State the advantages of a Mercantile Currency over one of Coin.

10. State some of the advantages and disadvantages of the Direct and the Indirect methods of Taxation, and show why it is necessary always to make the indirect method Discriminating.

II. In the Third Class, the work of the year has been confined to the elements of Formal Logic. We have covered the ground of the Classification of Terms, of the Distinction between Extent and Intent, of Definition, of Division, of the Classification of Propositions, of their analysis into Subject, Copula, and Predicate, and have advanced into the Doctrine of Inferences as far as through the principles of Immediate Infer-

ence, so-called. The method pursued has been essentially the same as with the Fourth Class, except that there has been a more decided effort to teach principles by examples. Fowler's text[1] has been made the basis of the instruction, and has been amplified when necessary, and criticised where it seemed to call for that treatment. The variations of view among the leading logicians have been presented, the different doctrines criticised, and the whole presentation of principles has been supplemented by oral and written practice upon examples. The time has been too short for the performance of the work in the best manner, and yet, considering all the circumstances, I have been highly pleased with the results. Subjoined are the two examination-papers used at the semi-annual and annual examinations respectively, from an inspection of which the scope and character of the work may be seen. The success of the class is indicated by the fact that only one member was conditioned at the final examination.

[Examinations of the Third Year's Class in Logic.]

I.—Semi-Annual Examination, January, 1873.

1. Write an original example, not in blank symbols, but in significant real terms, of each of the proposition-forms *I* and *Y*.

2. Point out all the respects in which the following proposition violates the conditions of a formal-logical definition:—

A Constitution is a document revealing the principles from which a National Life germinates, and which control the organization of a community for the purposes of government, or of the administration of the public interests.

3. Give an example of correct definition, by defining with precision a *Mathematical Limit.*

4. Point out all the errors in the following professed Division:—

The members of a community into Capitalists, Operatives, Catholics, Protestants, Merchants, Mechanics, and Agriculturists.

5. Give a correct and *complete* division of *Plane Figure*, down to its *infimæ species.*

[1] A *Treatise on Deductive Logic*, by Thomas Fowler, M. A. Oxford: at the Clarendon Press.

6. Reduce the following proposition to its regular logical form, so as to exhibit distinctly its subject, copula, and predicate: —

None but the brave deserve the fair.

7. Reduce the same to its logical skeleton, by substituting literal symbols for its subject and predicate, specifying the precise words for which the symbols stand, and then name the form (A, E, I, O, U, or Y) under which it falls.

8. Apply the directions in Question 6 to the following proposition: —

All that glitters is not gold.

9. Apply to the same proposition, the directions in Question 7.

10. Rewrite the proposition of Question 8 in such words as to bring out distinctly (1) its meaning *in extenso*, and (2) its meaning *in intenso*.

II. — Annual Examination, May, 1873.

1. In the following expressions, specify which of the italicised terms are General, and which are Singular: —

None but *the brave* deserve the fair.

Man's inhumanity to man makes countless *thousands* mourn.

A *bird* in *the hand* is worth two in the bush.

2. In the following, distinguish between the italicised terms that are Distributed, and those which are Undistributed, stating in each case the principle which determines the decision: —

Socrates was *wise*.

No *man* is *infallible*.

Some *men of genius* have been destitute of talent for affairs.

3. Of the terms *Animal* and *Brute*, which has the wider Extent, and why? Of *Conic* and *Ellipse*, which has the deeper Intent, and why? Why cannot the Extent or Intent of *Body* and *Spirit* be compared?

4. Divide the term *Students of the Massachusetts Institute of Technology*, down to its *species infimæ*, in accordance with the rules of Logical Division.

5. Point out the respect in which the following statement violates the Laws of Definition: —

A T-square is a sort of straight-edge.

6. Write (1) the Residuals, and (2) the Contraries, of the following terms: —

North, Probable, Black.

7. Write all the possible Opposites of the proposition *No philosophers are materialists*, and name the Grade of Opposition in which each stands.

8. Why would it not follow, upon disproving the foregoing proposition, that all philosophers are spiritualists? What *would* follow?

9. Convert the proposition *All observations are liable to error*, and state whether the conversion is Simple or Accidental.

10. Given the proposition *Some historians are not trustworthy*, (1) as true, and (2) as false, write all the legitimate Inferences by Opposition. Why can no Inference by Conversion be drawn from it? What is the legitimate Inference by Permutation, or Residuated Opposition?

The remainder of my work has been with the First Year's class, and has consisted in lectures upon the rudiments of Formal Logic, with especial reference to their application in the science of Language in general, and in that of the English language in particular. I felt that the attempt to present such a subject to a class at once so large and so inexperienced in such topics, and to present it, moreover, by lectures alone to a class as yet wholly without practice in taking notes, was, to say the least, an experiment. Nevertheless, from the peculiar nature of the views I felt obliged to present, no other course seemed open. I have therefore lectured to the class once each week during the entire year, giving up an hour at intervals to the business of testing, by proper questioning upon doctrines and examples, the comprehension of principles, and occasionally adding other hours devoted to a repetition of difficult matters in a more familiar form than that of the original lecture. A large, and, as it seems to me, decidedly valuable part of my work with this class, has consisted in a careful and sufficiently frequent revision of all their note-books, for the purpose of correcting errors, not merely of detail, but in the whole conception and plan of note-taking. The rapid and remarkable improvement of the class in this respect during the year, has more than repaid the drudgery of the process.

The results in the subject itself have perhaps been as good

as we had any reason to expect. From the subjoined papers, it will be seen that, while the work has been strictly rudimental, there has been no attempt to evade its difficulties. Upon the first, used at the semi-annual examination, some thirty-five were dropped or conditioned, out of a class of one hundred and fifteen. But of these, all but two made up their work successfully on the two papers marked II. and III. On the final paper, out of a class of seventy-six, three were conditioned, and none failed.

[Examinations of the First Year's Class in Logic.]

I.— Paper used at the Semi-Annual, January, 1873.

State under which of the Three Divisions in the Science of Language, each of the First Seven of the following statements belongs: —

I. The essential qualities of Style are clearness, appropriateness, and vitality. These it must have, no matter what the topic treated of, nor the end aimed at; what other properties it shall exhibit, will depend upon the nature of the subject in hand, the specific object to be gained in presenting it, or the special form of the composition.

II. If the thing denoted by an English verb occurs in what is called present time, the form of the verb changes to correspond with the number of the subject, provided the latter be in the third person.

III. A Noun is the name of any object of sense or subject of thought.

IV. The Possessive Case (*'s*) precedes the noun on which it depends.

V. One of the most effective means for giving vitality to style is the judicious use of metaphors; but a metaphor is an edge-tool, and the inexpert need to be wary in handling it.

VI. In the following expression from Ben Jonson's Eulogium of Shakspeare, namely, —

> ——— Soul of the age,
> Th' applause, delight, and wonder of our stage,
> My Shakspeare, rise!

all that precedes the word *rise* is the Compellative, or title of the person to whom the Imperative [*rise* (*thou*)] is addressed. *My Shakspeare* is the basis of this Compellative, and is modified by the appositive phrases, *Soul of the age*, and *Th' applause, delight, and wonder*

of our stage. It is noteworthy that this basis is complex, while the second appositive phrase has a compound base, *th' applause, delight, and wonder.* Of the Imperative, *thou* (understood) is the subject and *rise* the predicate; the copula is not symbolized.

VII. In the same expression, we may notice the forcible use of metaphor in the phrase *Soul of the age*, and the skillful metonomy in the expressions *applause, delight*, and *wonder.* Here the effect is put for the cause; Shakspeare *produced* applause, delight, and wonder, and the vivaciousness of the metonomy lies in the fact that the poet thus makes him appear so completely the life and soul of the effect he produces, as to be actually present in it, and utterly identified with it.

VIII. In the statement *Mercy is twice bless'd*, point out exactly how the Inner Aspect of Expression is exhibited.

IX. Show also in what consists the Outer Aspect, as presented in the same saying.

X. Exhibit the triune form of the proposition in the following exclamation, which Milton makes Death address to Satan: —

Back to thy punishment, false fugitive!

II. — Paper used to re-examine conditioned men, March 7, 1873.

I. In each of the following sentences numbered (1), (2), and (3), there are marked defects; in the case of each, state, *with the reasons for your opinion*, whether the defects are *logical, grammatical*, or *rhetorical:* —

(1.) The distance of the line from the origin is constant; but it's inclination to the axis of x is variable.

(2.) The line's inclination has variation in an unlimited gradation.

(3.) The inclination of the line may be changed at pleasure, and is therefore invariable; but the distance constant.

II. Point out which of the Three Forms of Universal Language is exhibited in each of the following expressions, taken as a whole: —

(4.) Because some men are hypocrites, is no reason for supposing that all men are so.

(5.) Merely to think of the hypocrisy of some men ——

(6.) Alas! to think of the hypocrisy of some men!

(7.) Just think of the villany of some people.

(8.) Some plausible people are villains at heart; because they do not hesitate to act basely whenever they feel sure that they will not be detected.

(9.) The deep-seated, crafty, unsuspected villany of many men that might be named.

III. Rewrite the following proposition in such words as, without in the least changing its meaning, will bring out distinctly the three elements of its triune form: —

(10.) A man may smile and smile, and be a villain.

III. — Paper used in Final Examination of conditioned men, April 9, 1875.

1. How many, and what, elements are to be found in every proposition?

2. How do you reconcile the apparent discrepancy between the answer you have just given, and the form of such a proposition as *We think*?

3. And how can you make out the requisite number of elements in *Go to the ant, thou sluggard*?

4. Above all, how can you find them in such a proposition as *Bethink thee*?

5. Is this a proposition: — *Better late than never*?

6. Is this: — *Brighter than all the stars of heaven*?

7. Is this an argument: — "Smith went to California, because he wanted to try a miner's life"?

8. Or this: — "He lay down and slept; for he was weary"?

9. Or this: — "Any side of a triangle is shorter than the circuit of the other two; for it is a straight line joining the same two points that they join by a broken line"?

10. Rewrite the following argument, so as to display in their proper order the three elements of its triune form, putting down (1) the Major Premiss, (2) the Minor Premiss, and (3) the Conclusion: —

"Because the shadows point westward, it is still morning."

IV. — Paper used at the Annual Examination, May, 1870.

1. Suppose that a certain piece of English were placed before you, and that you were required to criticise it (1) in respect to *purity*, (2) in respect to *propriety*, and (3) in respect to the *coherency and consistency of its propositions and their parts*, in which of the Three Divisions of the Science of Language would the three parts of your work respectively fall?

2. Decide, with regard to each of the following expressions considered as a whole, whether it is a Term, a Proposition, or an Argument, giving the reasons for the decision in each case:—

(*a.*) If I mistake not, it is with *Meister* as with every work of real and abiding excellence, the first glance is the least favorable.

(*b.*) One of the only three men of genius that have ever lived.

(*c.*) Is thine eye evil, because I am good?

(*d.*) There could no longer be any doubt of the prisoner's guilt; for he had committed suicide at the moment when new evidence, of an important and damaging character, was about to be brought forward.

(*e.*) That the court which tries him be pure, and the jury instructed in the cause; that the work be not condemned for wanting what it was not meant to have, and by persons nowise called to pass sentence on it.

3. Write the list of the Ten Categories, in their proper order, and state their principal use (1) in connection with the doctrine of Terms, and (2) in connection with that of Propositions.

4. Decide which of the following terms are Substantive, and which Attributive:—

(*a.*) The least favorable.

(*b.*) The first glance.

(*c.*) Every work of real and abiding excellence.

(*d.*) Of real and abiding excellence.

(*e.*) As with every work of real and abiding excellence.

5. Decide which of the following terms are Singular, and which General:—

(*a.*) Court.

(*b.*) The court which tries him.

(*c.*) Goethe.

(*d.*) Fidelity.

(*e.*) Persons nowise called to pass sentence on the work.

6. In the case of the Singular terms among the foregoing, distinguish between those which are Abstract, and those which are Concretely Individual.

7. In the list of terms in Question 5, point out those which are Simple, and those which are Multiple. In the case of the latter, state whether they are Complex or Compound. Finally, see whether

there is, among any of these terms, or among their component parts, an example of a Complemental term; and, if you find one, specify it.

8. Define the distinction between the Extent (or Denotation) and the Intent (or Connotation) of a term, and illustrate it in the case of the term *circle*.

9. Resolve the following propositions into Subject, Copula, and Predicate, without enlarging, restricting, or otherwise altering the meaning of either: —

(*a.*) Goethe is by many of his countrymen ranked at the side of Homer and Shakspeare.

(*b.*) To many of them I could do no justice.

(*c.*) What work was ever as the workman wished and meant it?

(*d.*) For this purpose, the most that I had room to say is said.

(*e.*) It is not tears which her fate calls forth.

10. In each of the following, give the final import of the predicate, by naming the category under which it falls: —

(*a.*) Fidelity is all the merit I have aimed at.

(*b.*) The duty of a translator is simple and distinct.

(*c.*) Some of these I may have failed to see.

(*d.*) The hero of the *Meister* is a milksop.

(*e.*) Goethe wrote *Meister's Apprenticeship* in his forty-fifth year.

For the future, I would recommend that the work from my chair begin with the second half of the Second Year, and continue throughout the Third and the first half of the Fourth, closing with the semi-annual examination of the latter. I should distribute the topics over that period as follows: —

Second Year: — Formal Logic,—Doctrine of Terms, Propositions, and Immediate Inference.

Third Year, *First Half:* — Formal Logic, — Doctrine of the Syllogism, and of Fallacies.

Third Year, *Second Half:* — Philosophy of Science, — Theory of Induction.

Fourth Year: — Philosophy of Science, — Logical structure of the various Sciences, especially of Mathematics; Theory of the Calculus; Philosophic Place and Value of the several Natural Sciences.

Of course it is to be understood that more time is to be given to these topics hereafter than we have been able to command the present year. The student must have ample time for the preparation of the subjects which have been assigned to my chair — time additional to that occupied with me in the lecture-room. I believe, however, that provision has already been made for this, at least in part, by a re-arrangement of the details in the other courses of instruction. When all our plans are completed, I cannot but believe that this department will fully realize all that was hoped for from it by those who urged its establishment. Respectfully submitted,

GEORGE H. HOWISON.

Boston, June 5, 1873.

REPORT OF THE DEPARTMENT OF DESCRIPTIVE GEOMETRY, STEREOTOMY, AND DRAWING.

To the President: —

The subjects composing this department were formerly distributed among several other departments; but, with the rapid growth of the school were formed into a new and distinct one, a year ago. The present is thus the first report relating to it, separately.

For this reason, as well as on account of a comparatively general unfamiliarity with the scope and meaning of its first two sub-titles, it seems due to the subject to present the matter, methods and work of the department, somewhat fully, however summarily, in a first report.

This may be conveniently done under distinct heads, as follows: —

I. *The definition of the department.* Descriptive Geometry may be popularly defined as the *geometry of drawing*; or, more exactly, as the system of principles, and exact operations founded upon them, by which all regular objects, both singly and in all possible combinations, can be so truly represented upon flat surfaces, that, from the drawing, the original can be constructed as it exists in the mind of the designer.

Stereotomy means literally the cutting of solids; as in Stone Cutting, Carpentry, and the shaping of mechanical pieces so as to produce certain motions by their combined action.

But, by the same refinement of speech by which *solid* geometry treats definite portions of space as empty volume, rather than as material bodies, stereotomy includes, in a geometrical sense, the cutting of immaterial as well as material forms, the cutting of the portion of space darkened by an opaque body, by a surface, which thus receives the shadow of that body; and the cutting of the immaterial cone of rays from a body to the eye, by a plane, which thus contains the perspective or picture of that body. Stereotomy thus embraces, in full, Shades and Shadows; Perspective; the shaping of mechanical organs relative to the motions they will produce, or the stereotomy of mechanism; the shaping of the elements of structures relative to their affording convenient and appropriate bearings, or the stereotomy of masonry, carpentry, and metal structures, as in stone-cutting, and roof and bridge articulations.

Drawing includes, *first*, the drawing of the many diagrams of a general character illustrative of the body of theory pertaining to Descriptive Geometry and Stereotomy; *second*, the preparation of finished working drawings of actual or proposed structures and machines; also free-hand and topographical drawing; and considerable preliminary drill in the merely manual operations in the use of instruments and drawing materials.

From this exposition, it is at once evident that the department, reaching as it does nearly every member of a large institution, is an extensive one; so much so, as already found by trial, that my foremost recommendation for the future is, that at the earliest opportunity all of the *second* branch of drawing just named be coupled with Geodesy, or the whole of Engineering field practice, and set off as a new department of Geodesy and Drawing; leaving the title of the present department to be Descriptive Geometry and Stereotomy. I suggest the union of geodesy with drawing, having for many years, in a former position, seen the smooth and excellent practical working of the

obviously natural plan of putting the construction of all maps of surveys in charge of the same hands that conduct the surveys themselves.

II. *The actual present composition* of the department now defined, is as follows; the subjects being arranged as given in the four successive years of the Institute course of study: —

FIRST YEAR.

1. Construction of Problems of points, lines, polygons and circles, in plane geometry.
2. The use of drafting instruments and materials.
3. Elementary, general and applied projections; or rudimentary and practical Descriptive Geometry.
4. Elementary Perspective, both of Forms and Shadows.
5. Elementary free-hand drawing.

SECOND YEAR.

6. Descriptive Geometry.
7. Shades and Shadows.
8. Topographical drawing.
9. Free-hand drawing.

THIRD YEAR.

10. Machine description and drawing.
11. Structure drawing from measurement.
12. Maps of land and line surveys.

FOURTH YEAR.

13. Stone-cutting.
14. Various professional drawing assigned by different departments.

III. *The work done.* Something has been accomplished during the past year in each of the above fourteen subjects, though less, it being a first and experimental year, than may be hoped for in future.

In the *first year* there were about thirty exercises per man, of mingled instruction, interrogation, or blackboard demonstration, upon the body of principles, or theory, connected with the numerous additional drawing exercises; the whole occupy-

ing about ten hours per week. In these exercises an aggregate of not less than forty rationally constructed, not copied, plates, nine inches by thirteen inches in size, were made by each student, besides the execution of many plates in Free-hand Drawing.

In the *second year* there were about forty class exercises, as above, on the theory of the subjects pursued, connected with the construction of about sixteen plates, ten inches by fourteen in size, in Descriptive Geometry and Shades and Shadows, besides those made in Free-hand landscape and object drawing, and in Topographical drawing.

In the *third year*, owing to excess of other work, a little only was done in Shades and Shadows and in Machine Drawing, in the first half of the year. But a very satisfactory beginning was made in the second half, with the drawing of various roofs, bridges, and other structures in the vicinity, suited to the various professional courses chosen by different students. The class entered on this work with gratifying and commendable zeal, and made drawings, from measurements of a drilling machine, the new Providence Railroad Depot roof-truss, the Lowell Railroad drawbridge, an iron road bridge at Waltham; and of smelting and gas furnaces, all under instruction; also maps of surveys.

With the *fourth year* class, various hindrances prevented more than a bare beginning of a course in stone-cutting; and the construction by each student of one bridge drawing, generally one of several bridges visited during the preceding summer.

To the three regular architects of the Third and Fourth Years united, a short course in Higher Perspective of Forms and Shadows was given, with the peculiar pleasure always arising from the instruction of a small class of interested and uniformly qualified students. A short special course in Elementary Projections of bodies and of their shadows was also given to the Special students of architecture belonging to the Third Year.

IV. *Remarks and suggestions.*

a. The force of instruction for accomplishing the foregoing work has consisted of one professor, three official assistants — two of whom gave but a part of their time to the department — and six student assistants. This may or may not seem a large force, but it must be remembered that while the occupants of some chairs seldom or never come in contact with more than a dozen students, the present is one of several of the more comprehensive departments, whose instructions extend to nearly all of our three hundred and fifty students.

It seems generally better to have official, rather than student instructors; and, with the present number of students, I would urge the advantage of employing the full time of three official assistants, or its equivalent, with from two to four student assistants, according to the nature and amount of their services.

b. Methods. These have embraced, under the head of *instruction*, brief familiar exposition, accompanied by Models and Diagrams and the expounding of text-books, with careful pointing out of cardinal principles and directions for proper use of the book in order to gain a clear view and firm grasp of the subject. Also under the head of *recitation*, individual and general interrogation, blackboard demonstrations, and regular and informal written examinations.

In reflecting on the character of the many examination papers looked over during the year, it has occurred to me, often and forcibly, that in some things they are not a full substitute for oral examinations, though on the whole decidedly preferable, independently of the size of the school. Their strong point, to my mind, is in the opportunity they afford for each man to tell substantially all he knows of the subject in hand, or at least enough to enable the examiner to form, generally, a sure judgment in each case.

Their weak points thus far noted are two. First, their undoubted tendency to encourage a slighting of daily term work, and a "cramming" at the end, on the part of all who do not study from principle, or fondness for learning; that is, if

the *final* term papers, only, are wholly or mainly relied on to determine the student's standing. This defect could be obviated by making the student's standing depend on the mean of the results of all the tests applied to him, or at least of all his written examinations.

The second defect, of very different nature from the last, is that written papers are liable to betray perplexing ambiguities as to what the writer really means, and wasteful misunderstandings of either the point or the scope of the questions; defects arising not from obscurity in the question to the well-prepared student, but to a mistiness or incompleteness in a less perfect student's knowledge, while nevertheless he is not grossly deficient. Now any exact subject may be said to embrace facts, principles, and problems. The latter only would seem to be most fully provided for by examination papers. But in ten minutes, by the clock, from twenty to forty questions, by actual count, according to their character and the readiness of the student, can be asked on facts and principles in which ambiguities and misapprehensions can, unless in cases of real deficiency, be instantly corrected, and a very telling exhibit secured of the quality of the student's command of his subject. Now it takes at least ten minutes to look over an examination paper. If, then, some way could be devised to divide ten to fifteen minutes between oral and written examination, I would submit that more comprehensive and certainly decisive results could be attained, to say nothing of the superior life and interest of an oral examination.

c. New models. A perfect set of models can doubtless only be built up gradually, as found by experience to be wanted. The more immediate needs of the department in this regard are, a set of about fifty cheap, simple objects, such as any carpenter can make, for use in drawing perspectives of actual objects, from measurement; a couple of bridge models costing about $150 each, and a small appropriation, to be drawn upon from time to time for approved and specified models in Descriptive Geometry, Mechanical Elements, and Stone-cutting.

The foregoing are all the topics that have occurred to me as being of interest relative to my department, to those having the welfare of the school in charge; to whom, and chiefly to yourself, they are respectfully submitted.

S. EDWARD WARREN,

Prof. of Descriptive Geometry, Stereotomy, and Drawing.

DEPARTMENT OF ENGLISH AND HISTORY.

Pres. J. D. Runkle:—

SIR:—I hereby present the following report of my doings during the past year in the departments of English and History.

The difficulty of securing a sufficient amount of time for English studies has continued to embarrass me, and must continue to do so, so long as the preparation for the school continues so imperfect. Practically a large majority of our regular students have to crowd four-and-a-half to five years' mathematical and scientific work into four years; and this leaves but a small amount of mental energy to be devoted to studies not strictly professional. There is one, and only one remedy for this difficulty, and that is a better preparation; and that not more, or even so much in English and mathematical as in elementary scientific study. In consequence of the very defective condition of school instruction in science in this country, our students have practically to begin the study of the very rudiments of physics, chemistry and the different branches of natural history at the age of sixteen or seventeen, a period of life at which, if our schools were perfectly organized, these elements would all have been acquired. By this postponement these studies become unnaturally difficult of acquirement, and the necessity of making up these untimely arrears of professional study stands in the way of the success of the English department, by depriving it

of the time which might otherwise be devoted to English studies. An addition has this year been made to the requisites for admission on the side of mathematics: it is to be hoped that the time is not far distant when improvement in school teaching will allow us to assume the possession of a reasonable amount of knowledge of the elements of physical science on the part of young men of the age required for admission.[1]

Till that time comes, no proper balance can be established between English and scientific studies within the school. The time required for making up arrears in professional studies *must* be taken from that which should be devoted to general training. The professional student comes for a distinct purpose; he wishes, for instance, to be made an engineer, and he must be trained so thoroughly in engineering studies that his bridge will not break down through faults of construction. It would be small comfort to his employers if that should happen, that he could report in Addisonian English, and with unimpeachable logic the precise reasons why it broke down. It is better, if the choice must be made, even that his report should contain English words misspelled, through the defects of his primary school learning, than that his bridge should prove defective; though his literary deficiencies cannot be considered otherwise than unfortunate, and the misspelling engineer can hardly claim that he has received a complete or symmetrical education. All that can be said is that his not having received it within four years cannot be imputed as a fault to the Institute of Technology.

What course to take under such circumstances has been to me from the beginning a very puzzling question. To exact from the students the amount of mental effort which would be required by a course of English studies pursued with the same thoroughness as is required in their scientific studies, is obviously impossible; for the complaint is now very general that our students are overworked, and to add to minds already over-

[1] Even now I think it would be feasible to require an entrance-examination in one or more of the excellent "Science Primers," now in course of publication in England.

burdened with scientific study the amount of labour required for the thorough study of all the great subjects which a properly conducted english course contains, would be simply to break down the student altogether. On the other hand, to reduce requirements in English to the paltry minimum of correct spelling, and the writing of business letters, would be to abandon all claim on the part of our institution to being called a place of liberal education.[1] I cannot claim that I have completely overcome the difficulty, for it is in its nature unsurmountable; and a teacher in the English department of the Institute must for the present, be contented with very modest, not to say incomplete and imperfect results. One consideration has guided me in the course I have pursued in my literary and historical instruction, and it is a very important one in connexion with such studies, that they are precisely of a kind where much may be done, by proper effort on the part of the instructor, to implant taste and excite curiosity even where the opportunity is wanting for systematic or exhaustive study. The mathematics required by the engineer are a precise and definite subject, to be thoroughly mastered by the student within a given period, as an absolutely essential qualification for his degree. A knowledge of literature and history is no such definite quantity, and by its very nature is not to be arrived at by such precise methods. Taste cannot be taught, nor a knowledge of history be communicated in twelve or any other definite number of lessons, though a knowledge of geometry may; but it may make an infinite difference to the student in after life whether some love and appreciation of literary and historical studies was or was not implanted in his mind in the course of his school education; and that love and appreciation may be instilled by methods different from the rigid and exhaustive ones required in the purely disciplinary part of his studies. It may

[1] It is a point upon which I am not qualified, and do not presume, to give an opinion how far our present scientific courses might be curtailed of scientific superfluities, but I am clearly of opinion that if there are any such superfluities they should be sacrificed in preference to any part of the student's general training.

fairly be maintained, therefore, that while in the latter case the main stress of the labour falls upon the student, and his success depends upon the amount of his hard work, there is learning of a different kind where the burden of the labour falls upon the instructor, and his difficult task is so to digest his materials as to produce a valuable result with only a minimum of effort on the part of the pupil. This seems to be the part to be played by instruction by lectures on subjects which cannot, either through their very nature, or through adverse circumstances, be dealt with by more rigorous methods. And in my judgment it would be a gross mistake to undervalue such instruction, if only it be good of its kind. From the very nature of things, and the vastness of the field of knowledge, every man's acquisition must consist of two parts, that which he knows systematically and thoroughly, and that which he knows partially, and only well enough to appreciate and desire to know better. To be equally master of all subjects, is given to no finite mind. It is much, if in education we teach the student to avoid the presumption of undervaluing the subjects with which he is unacquainted. That the student of science should at least be partially acquainted with literary and historical studies is infinitely better than that he should have no knowledge at all; and where a taste for such studies is not by some means implanted in school or college, it is rarely, and by accident, that it is acquired amidst the engrossing occupations of after life.

Such a course will undoubtedly be inferior in point of systematic thoroughness to the professional part of the student's instruction. It will draw less on the memory, while, on the other hand, it will aim to cultivate taste and judgment, excite curiosity, and lead to a love of extra professional reading and the acquisition in after life of knowledge on subjects which should interest the student as a man and a citizen. Many of the topics it deals with are such as had better not be handled by rigidly systematic methods; a taste once excited, a complete knowledge must be left to the voluntary efforts of after years. To make enforced tasks of what should be pleasurable mental efforts — ef-

forts which are nothing if not pleasurable — is the way in which literary instruction is too often overlaid and smothered by scholastic pedantry. Some of the best results of these studies are such as cannot well be gauged by competitive examinations or exhibited in answers to sets of printed questions.

I do not mean that such instruction can dispense with all labour on the part of the student, or that there are no methods of testing its results; I only mean that the amount of his voluntary labour may more safely be reduced to a minimum and that the amount of absolute knowledge must be very much less than that of the subject on which the stress of his mind has been exercised. Even though it may be impossible for the student to acquire the same amount of knowledge of the details of history as of the details of chemistry, he may at least gain at school an adequate conception of what the study of history really is, may have it exemplified by the more or less detailed treatment of some one period, may acquire something of what may be called the historic sense, and the habit of looking at political and social questions, whether of the present or the past, from a historic point of view. This is not every thing; but it is better than entering life without any historic training, or with only the schoolboy notion of history as being a dry collection of names and dates. In one sense it is superficial; but in another sense such instruction, addressed to young men whose minds are beginning to mature, and who are learning to think independently on important subjects, may be made to contribute to one of the most precious results of all training, namely, the habit of vigorous independent thought on subjects outside the narrow limits of their professional practice.

It has thus been my not very easy task to try to awaken a loving and real interest and an adequate appreciation of studies in the pursuit of which I could not throw the burden of much labour on the students themselves. I have heretofore erred mainly in attempting too much — not too much for what the Institute ought to be, and is destined to become, but too much for what it really is at present. The experience of a good many mis-

takes has enabled me to improve somewhat this year upon the results of the past sessions, and to report more definitely what I can reasonably expect to accomplish in the future.

I began this year with the new class with instruction from a school treatise on rhetoric and composition. This is not properly work for the Institute, but it may fairly be placed beside the necessary review of algebra and geometry with which the mathematical work begins. Every well-instructed young man of sixteen or seventeen should bring with him, as the result of the last years of his high school training, fair ability to write his mother-tongue, and a good knowledge of the elementary principles of rhetoric. It would be making a liberal estimate to say that fifty per cent. of our classes have attained such a standard, and it is a difficult question to answer, where a class has to be instructed as a whole, whether the instruction should be addressed mainly to the superior or to the inferior half. Where a class cannot be graded according to proficiency, the practical result is a compromise, which sometimes bears rather hard on the older and superior students: but my judgment inclines me more and more to the plan of taking up my subjects as nearly as possible at the point where I ought to begin, supposing the elementary instruction to have been altogether satisfactory. To do otherwise is to put a premium on insufficiency, and to degrade the function of the Institute. The bad spelling of a portion of the students has called forth much criticism, but it is a question whether the true remedy is to set students of seventeen down to spelling-lessons again.[1] So elementary lessons in the structure of sentences suited to the capacities of children furnish very uninviting food to young men. Young men cannot be turned into children again, and it is not desirable that they should be. Nature and life have been maturing their minds if school has not been instructing them

[1] For the benefit of students who have not studied Greek and Latin, I purpose hereafter to give some special lessons in the spelling and derivation of technical terms derived from those languages, the department in which the students' spelling is apt to be weakest.

properly, and though the loss arising from imperfect elementary training may not be wholly made up by any plan, yet I am confident that the principle of taking up my subjects in a manner adapted to the student's age rather than to his want of literary attainments, by producing a more living interest in the subject, involves less loss than too much belated attention to the making up of elementary deficiencies. Either doctrine, it is true, may be carried to an extreme. A teacher may, on the one hand, easily lecture over the heads of his pupils, while he may on the other, destroy all vital interest in the higher and most valuable parts of his subject by a too pedantic attention to petty details. I have tried to adopt an intermediate course. While taking the ground that the Institute does not offer itself to the public as a teacher of spelling, or punctuation and the rudiments of grammar and composition, I have given as much incidental help as possible, by causing written exercises to be corrected, and by going rapidly over the elementary parts of a school rhetoric.

I proceed, however, to a more mature and manly style of exercises as soon as possible, throwing the burden of making up elementary deficiencies from that time upon the student himself. These elementary deficiencies have arisen mainly from carelessness arising from lack of interest in school lessons, and make themselves up very rapidly whenever a living interest in literary subjects has once been excited. Deficiencies in spelling are made up if the student acquires a habit of reading; and the power of expressing his thoughts in clear and simple language is the gradual result of his whole mental discipline, when it is accompanied by even a minimum of practice in that direction. The power of expressing thoughts in writing on any subjects on which they have ideas to express, possessed by our present senior class will compare, I think, not unfavorably with that of any similar body of young men who have had no more time to bestow upon the subject than they have had.

I attach but little value to the writing of "Compositions," or the study of treatises on rhetoric after the usual fashion of

our schools. It is the cardinal principle of all good writing that a man must have something to say, and the desire to say it. Young men who have read and thought but little, have very little to say, and with them the enforced practice of composition degenerates into the habit of diluting a very few thoughts with a great number of words, than which no habit can be more fatal to good thinking. It would seem wiser to prepare for the time when they may themselves have something worth saying by occupying them with the study of writers of established excellence. And in this way every good manual in every department of study, except the most technical, is really a constant and most valuable exercise in the study of English; and the learning to think clearly on scientific subjects, is excellent training for thinking clearly on subjects non-scientific. It is in this way I am glad to explain the real progress made by our students in their matters of English where so little labour can be directly bestowed on the subject.

What can be accomplished directly amounts practically to this:—A review, at the beginning, of the rules for good writing laid down in the Rhetorics, accompanied with an insufficient amount of practice. With the Rhetorics still in hand, as books of reference, I propose to follow this with the critical reading of good specimens of modern English as studies in style and expression, with the occasional task of a written analysis of some good specimen of an English essay, or an original paper on some subject previously discussed in the class-room. These practical exercises are accompanied by a series of lectures on the history of English literature, which take the shape of a commentary on some short manuals of English literature and English history, which the students will be required to have in hand simply as books of reference. *Lessons* in such manuals are, in my judgment, worse than futile. The only labour required of the students in connexion with these lectures, will be that of taking notes, and the examinations will be conducted with the students' manuals and note-books open before them; the examination not being intended as an exercise of memory,

but as a test of their interest, their taste, their attention and good judgment. The want of a lecture-room equipped with proper facilities for writing, has hindered me from fully realizing this plan; and I respectively suggest that such a lecture-room is an absolute necessity to the English department.

The course in History has been conducted on substantially the same plan, except that for the sake of economizing time and assisting students in their study of foreign languages, the manuals used have been in the French language.

With the second class I have devoted the two lessons per week to the subject of modern history, beginning with the middle of the fifteenth century, and using the French "Histoire des Temps Modernes" of Duruy, as my manual. My custom has been to translate it slowly with oral comments, the class having the text in their hands. This was the exercise for about one-half the time, the class being required to make each week a short bit of written translation as an exercise in English. The other half has been occupied with lectures and oral lessons on the period in hand, with abundant reference to collateral reading. I have endeavored, in my treatment of the period to which we have confined ourselves, to give the students my idea of the proper method to be pursued in studying history, if they should have leisure for it hereafter, and of the true objects to be kept in view as the proper aim of the study. I have connected the study of a past era with as much information respecting the present condition of the countries as the time allowed. Having been obliged to give these lessons to a large class in a lecture room destitute of any accommodations for writing, I have not been able this year to insist upon as much systematic note-taking as I could have wished.

I have devoted the one hour per week assigned me with the third class to a similar translation with oral comments of Guizot's "Civilization in Europe." The book is the best I can find for the purpose, that of giving a brief and clear outline of the philosophy of the history of modern Europe to students who have not time to study it in detail. It is also a model of

perspicuous style, and it is the general verdict of the class that they have derived much assistance in mastering the language from this sort of exercise.

With the fourth class I have occupied my single hour per week chiefly with the discussion of subjects connected with contemporary history and politics. During the first half of the term the students themselves frequently occupied the hour with the reading of their own papers — reports on topics selected by themselves, or abstracts of pamphlets or review articles loaned to them by me for the purpose. Very good papers of this kind were read to the class, and it is very much to be regretted that more time cannot be devoted to such exercises. During the latter part of the term I have given a few lessons on contemporary history, based upon the statistics of Martin's Statesman's Year-book, with a view to making the students somewhat familiar with the present aspect of European affairs and with the resources and present social and political condition of the leading nations. I am greatly impressed with the importance of making a knowledge of the living history of the day the leading object of the historical instruction in such a school as ours.

The use of French manuals has been so far successful that I intend to try the experiment of a German manual as the foundation of my lessons on constitutional history to the fourth class, next year.

With the students in the department of "Science and Literature" I have read Shakespeare's Merchant of Venice and selections from Chaucer's Canterbury Tales, in the carefully annotated editions published in the Oxford Clarendon Press Series of English Classics, reading along with them some good specimens of criticism. It would be difficult to make Shakespeare and Chaucer otherwise than interesting, and the exercises are very well as far as they go. But it is, I think, much to be desired that English studies should eventually be made to play a leading and not a subordinate part in the course in "Science and Literature." The students who enter this department

are, as a rule, not looking forward to the practice of either of the technical professions, but come to the school rather for purposes of general education, and with the desire to procure for themselves the best general preparation for active life. They are not therefore under the same pressure in regard to purely scientific study as the students who are aiming at a technical degree. I am of opinion that the "Science and Literature" course therefore should be something more than what it is at present, a mere miscellany made up of odds and ends of the regular scientific studies, but something distinctively different — a course in which English studies should enter as a solid and disciplinary part of the student's training. The number of students in this department is now sufficient to form a class — the instruction of Prof. Howison leaves nothing to be desired in the department of logic, and this year will give us additional facilities for thorough instruction in modern languages and a favorable opportunity seems offered for arranging a course of study of a less technical character than that of the chemist, architect, or engineer, in which foreign living languages, the English language and its literature, civil history, the elements of municipal, as well as constitutional law, physical, political and economical geography, and other studies which go to form the future man of business, shall take the place of that portion of the higher mathematics and purely professional scientific training which such students would omit. It will be for the Government of the Institute to say whether such an enterprise shall be undertaken. A strong argument in its favor must always be, that a valuable *systematic* course of study might thus be provided for a large number of students who, through want of scientific preparation, or inaptitude for higher mathematical studies, at present either drop into all kinds of miscellaneous specialties, or drop out of the school altogether. For a good many years to come it seems likely that a large number of students will continue to enter our school who are either unable to compete for our strictly scientific degrees, or do not desire to take them, and it seems

highly desirable that something more systematic should be provided for them than our frequent "special" and "partial" courses. It would be altogether undesirable that the high standard at present set for the attainment of our purely scientific degrees should be lowered in order to meet the wants of students unapt or disinclined to higher scientific studies. I think it is not too much to say that for these students the Institute has already at its command the materials for forming a parallel course of study, equal in disciplinary value and in practical usefulness to the strictly scientific courses which are now so thoroughly carried out.

I must again respectfully represent to the Government that the wants of the English department are great in every direction. It needs a lecture room of its own, equipped with proper accommodations for writing, and with facilities for the exhibition of maps and other apparatus, and in immediate connexion with a larger and better-appointed reading-room. In the reading-room it needs a larger collection of well-selected books of reference. In addition to books of reference, it is very much to be desired that it should have a selection at least of the best works of standard English and American writers.

All which is respectfully submitted,

W. P. ATKINSON,

Professor of English and History.

REPORT OF AN EXCURSION MADE IN THE VACATION OF 1872–73.

In the summer of 1872, a party of twelve students, under my charge and that of Instructor Hoyt, visited some of the principal bridges of the country, and other works of interest to engineers. The party went first to Albany, to inspect the bridge over the Hudson; thence to Philadelphia, where the Baldwin Locomotive W rks were visited; thence to the bridge and iron works at Phœnixville, where, by the kindness of Mr. Coffin, the various steps in the manufacture of iron bridges, beginning with the ore, were observed, and much valuable information gained; thence to Pottsville, to visit the coal region and the steep gradients on the Broad Mountain tracks; thence to the railroad shops at Reading, where Mr. Paxon, the master machinist, conducted the party through the works and pointed out many interesting processes in the manufacture of engines and cars; thence to the Bessemer Steel Works near Harrisburg, where Mr. Felton, the President of the company, gave the party an opportunity of seeing the whole process of manufacturing steel; thence to Pittsburgh, where the Keystone Bridge Works were visited under the guidance of Mr. Linville, and the various parts of the great steel arches of the St. Louis bridge over the Mississippi were seen; thence to the Oil Regions, by the Alleghany Valley Railroad, as far as Peters-

burg; thence to Cincinnati, where the new railroad bridge and the suspension bridge were the principal objects of interest; thence to Louisville, where the bridge over the Ohio, and the canal around the falls, and the Louisville Bridge Company's works were visited — these last under the guidance of the company's engineers, Messrs. Vaughan and Trafton; thence over the Louisville and Nashville Railroad as far as Cave City, to see the bridges on the line and to visit Mammoth Cave; thence to St. Louis, where the abutments and piers of the great bridge over the Mississippi and the Water Works were visited.

At St. Louis the students were divided into six parties, and to each party was assigned one of the principal bridges, which was to be visited and studied in all its details, with a view of giving a full description of the work, accompanied with accurate drawings. The party was, in effect, here broken up, as its members had generally to return by different routes, in order to study the works assigned to them. This report should not close without a grateful acknowledgement of the courtesies so generally shown to the party by the railroad companies, and by the engineers, master machinists, and others connected with the establishments visited.

JOHN B. HENCK,

Prof. of Civil and Topographical Engineering.

PROFESSOR ORDWAY'S REPORT ON THE VACATION EXCURSION OF 1873.

President Runkle: —

DEAR SIR: — Visits to manufactories and metallurgical works have always proved a most important adjunct to the instruction given by us in Chemical Technology, and I am happy to say that the past year has witnessed no diminution in the number and variety of these excursions. It is very pleasant to find so much liberality as we have experienced on the part of gentlemen in charge of establishments not generally open to visitors, and to learn that our manufacturers take so much interest in the work and objects of the Institute.

In the department of Mining and Metallurgy it is a part of our plan to give students opportunities for more extended and continuous attention to actual mining, ore-dressing, and smelting operations, than the regular course of study in term time admits. In accordance with this idea, a long planned expedition to the Adirondac iron region has been successfully carried out since the close of the school year.

Arrangements were made for a party of nine students, together with Prof. Richards and myself, and on the morning of June 24th we met at the Lowell depot, arrayed in garments

suitable for rough usage, each furnished with note-books, hammer and haversack, blanket and poncho, and the minimum of baggage required for a three weeks' tour. Our first destination was Warren, N. H., where we spent the afternoon in visiting the lead and zinc mine, which has been worked, at intervals, for many years. The present happens to be a stand-still period, and as the underground part of the mine was filled with water, we had to be content with examining the extensive open cut and the large piles of zinc ore at the surface. Still there is much to be learned there, and we were amply repaid for our three mile' walk. The next day we proceeded by rail to North Lisbon, on foot to Franconia Village, and then by wagon to Franconia Notch, and back to Lisbon. At Franconia we devoted some time to the old charcoal iron furnace, which is in pretty good condition, though it has not been in blast since 1859. The fact is, Franconia is not now favorably situated with respect to fuel, as wood is too scarce to supply an iron furnace many years, and the village is too far inland to allow the use of anthracite. We were shown good specimens of copper ore which has lately been found in the town, but had not time to visit the opening from which it came. We reached Lisbon at a late hour, but were up betimes the next day, and improved the morning hours in visiting the stamp mills originally built for treating the gold bearing quartz of a mine about two miles north of the village. The machinery was afterwards run to powder a rock from Lyman, which was in great demand not long ago, on account of its supposed virtues as a fertilizer, and lately Dr. Ray, whom some of us met two years ago in Colorado, has reopened the gold mine, and is using the mill for extracting the precious metal by a peculiar process of amalgamation. Dr. Ray reports the quartz as containing $35 worth of gold to the ton of rock, and at this rate the mine should pay, if the separation of the gold is properly conducted. It seems to us that chlorination is the proper method of treatment.

Lisbon was not included in the route originally laid out, and

it was not thought best to tarry for the sake of visiting the mine. So at half past eight we were in the cars bound for Ely, Vt.; and at one o'clock, after a short stage ride, we found ourselves at West Fairlee. After securing quarters and disposing of a very acceptable dinner, we walked on a mile and a half to the adjacent town of Vershire, and made a preliminary examination of the extensive copper mine and smelting works of the Vermont Copper Mining Co. This reconnoissance enabled the professors to make, in the evening, a systematic allotment of parts for the morrow, so that each student should be responsible for the full and exact observation of some particular branch of the work, besides gaining a general knowledge of the whole. By the kindness of Messrs. Daniel and William Long, the skilful gentlemen in charge of the establishment, and of Mr. Ely, the President of the Company, every thing was opened to our inspection, and we are indebted to them for devoting much of their time to us during our stay at Vershire and West Fairlee. The next day we crowded into an ore car, and with crouched heads, rode into the horizontal adit nine hundred feet, and then, in company with Capt. Pascoe, explored the mine below and above, coming out into the hot summer air at a point high up the hill. The captain also conducted us into a lower horizontal drift, which is being carried forward rapidly with the aid of the Burleigh drill to intercept the deeper parts of the workings. After a needful lunch the afternoon was devoted to a close study of the picking, washing, and smelting operations. We had hardly expected to find in New England a copper mine turning out nine hundred tons of picked ore per month, and it was to be regretted that so little time had been allotted to this rich mineral region. Two weeks might well be given to the copper mines of Vershire and the adjoining towns, Corinth and Strafford, together with the unworked lead mines of the neighboring town of Thetford.

Saturday morning a conveyance was procured for ourselves and baggage to the railroad at Sharon, and, while the horses were resting at noon, we made a somewhat hurried detour on

foot to the copperas works and copper mine at Strafford. The manufacture of sulphate of iron was in full operation, but the mining was suspended for the time being. Night found us at Burlington, ready to enjoy a Sabbath of rest. The great lumber interests of Burlington did not immediately concern us, but before the arrival of the steamer on Monday most of the party took occasion to visit the pleasant grounds of the University of Vermont. A strong wind somewhat delayed the passage of the boat southward, but we arrived at Port Henry in season for dinner. Thus in somewhat less than seven days we reached the chief point for which we started. Here centres the present iron interest of the Adirondac region, and here are to be seen the sources of the ore which is shipped to all parts of the country. Commencing work at once, we called on Mr. Foote, the obliging Superintendent of the Bay State Iron Co.'s furnaces, and were soon engaged in studying the smelting of magnetic iron ore, with anthracite coal, in furnaces of the most approved construction. These two high furnaces turn out over fifty tons of pig iron in twenty-four hours. A little more than half a mile south, the Cedar Point Iron Co. are building a new furnace, for which Whitwell's regenerative stove will be used. Mr. Witherbee, the Superintendent, is the first in the United States to adopt this blast heater, and this is the first anthracite furnace in which the recent invention is to be tried. Walking down to Cedar Point in the evening, we had a good chance to see the great number of elementary parts which enter into the making up of the iron smelting works of the present time.

Tuesday was devoted chiefly to the examination of the famous Cheever ore beds, a mile and a half north of Port Henry furnaces. In the forenoon we went by a long stairway, down a steep incline, into the middle bed, which has an average thickness of some six feet, and is of unknown extent. After the dinner hour we were lowered in the iron bucket, half at a time, down the perpendicular shaft three hundred and twenty-five feet in depth, to the lower bed. This vein of clear, solid magnetic ore is from five to fifteen feet thick, and the

working has extended over many acres underground. There was ice in the bottom, and the air of the mine stood at 38° F. After travelling about a long distance in this atmosphere, and coming up one of the inclined shafts, by an almost interminable stairway, into the open air of a hot July day, we found the contrast more striking than agreeable. Any farther vigorous effort was not felt to be desirable, but due attention was given to the inclined railway by which the picked ore descends three-fourths of a mile to Lake Champlain, drawing back the empty cars or coal to run the engines for hoisting and pumping. Three rails are here made to do the duty of four, by having a really double track where the ascending and descending cars meet each other. Wednesday was spent in a closer study of the blast furnaces with all their appurtenances, and a pleasant evening row on the lake to the old fort at Crown Point closed our explorations from Port Henry as a base. Early next morning we proceeded, with all our baggage, to Mineville, seven miles distant, over the Lake Champlain and Moriah Railroad,—a road built solely for transporting ore, and very remarkable for making an ascent of thirteen hundred feet in going the seven miles. About thirteen hundred tons of ore per day are taken from the immense deposits among the hills, over this road to the Lake, to be carried thence by canal boats or cars to all parts of the country. Under the guidance of Mr. Roe, Superintendent of the Port Henry Iron Co.'s mines, we were lowered down an open cut into a bed a hundred feet thick, and how much more is not yet known. Here is mining indeed, or it might almost as well be called quarrying. With so vast a vertical face exposed, the horizontal progress is slow, and the underground working is as yet of moderate extent. There was ice in the lower part of the open cut. It is said to be too cold to work in winter at the bottom of the mine, and the workmen are then kept on higher levels. After traversing the underground openings we ascended by ladders. The hoisting machinery at this mine is of admirable construction, and the power for pumping is transmitted from the engine house

down into the shaft by wire ropes like the ropes used for hoisting.

Near by is the old Sanford ore bed, in which the magnetite was at first found largely mixed with apatite, and was therefore of little value, though a preposterous scheme was set on foot to work this vein for the sake of the phosphate of lime, which was cleansed by means of magnets and made into a fertilizer. It did not pay; but it is found that the ore improves as the vein runs deeper, and work has been resumed in the Sanford bed by Witherbee, Sherman & Co. During the noon hour we went to the New Ore bed half a mile off,—a bed remarkable for yielding very large crystals of magnetite. Three of us descended some nine hundred feet, by the inclined stairway, to the heading, where a few men are kept at work. The ore needs some picking, and it has to be carted to the railroad, so that the cost is enhanced, but it is in demand on account of its purity. The Barton bed, high up the hill, crops out in many places for a distance of half a mile, and in years past has been worked by several openings. Most of the excavations are abandoned and full of water, but the Bay State Co. are still smelting some of this ore. While a heavy shower was clearing up, we found time to dispose of the ample dinner which had been made ready for us. In the latter part of the day we visited the charcoal blast furnace of Witherbee, Sherman & Co., about two miles away. This is an old furnace remodelled and modernized, and it presents some notable peculiarities. Everything is well arranged and the work is conducted with skill. The charcoal is made in a set of rectangular kilns close by the furnace. The ore is carted from a distance. From the increasing scarcety of wood, this furnace must in a few years be numbered among the things that were.

The growth of Mineville has been rapid, and there is little house room to spare. We had therefore to bring our blankets into requisition, in sleeping on the floor of some unfinished rooms in a new house. The hard pine mattress proved no hindrance to sleep, and the morning of July 4th found us well

rested and ready to move onward, a patriotic relaxation from work being deferred till the next week. It was not easy to procure conveyance on the national holiday, but at length we proceeded by wagon to New Russia to study the bloomery forge there. Work was suspended, but there was all the better chance to examine the apparatus that pertains to this American improvement on the oldest and simplest method of making tough iron. In the establishment at New Russia there are four forges, each capable of turning out three hundred pounds of blooms every three hours. We were busily occupied an hour or two in noting the roasting stacks, stamps, elevator, jiggers, blower, heating pipes, forges, cranes, trip-hammer, steam boilers, and engine, — each one giving special heed to his assigned details, and subjecting the good-humored workmen to a thorough catechizing. Another ride of some miles brought us to Elizabethtown in good season. After tea there was still enough daylight left to allow us to look into a well appointed bloomery, not now in blast, which showed some modifications not seen at New Russia.

It was now unanimously decided to make a diverson to Tahawus, or Mt. Marcy, in the wilderness. So on Saturday, leaving all superfluous baggage at Elizabethtown, we secured a wagon to take us to the head of Keene Flats, on the Ausable River. And here, tormented by myriads of black flies, but having comfortable rooms and plenty to eat, we spent a quiet Sunday. There is no morning service at Keene Flats, and it seemed not inconsistent with the proper observance of the day to take a walk of a mile and a half into the woods, and view a most romantic waterfall. The crumbling away of a thin trap dyke has here made a gap in the high, precipitous rock, and through this channel a little stream from the Giant of the Valley falls down a hundred feet or more. Farther up the stream occurs another pretty fall of perhaps twenty-five feet. In the afternoon, all who chose rode with our worthy landlady to attend divine service in the little red school house at the Flats.

They told us that the ascent of Tahawus usually takes three

days,— the guides are paid by the day,— but we determined, if possible, to spend the night of Tuesday in Elizabethtown. Rising therefore before daybreak, we got through our breakfast, took two days' rations in our haversacks, strapped on our blankets and ponchos, and began the march through the woods at five o'clock. The guide carried the fresh meat in his knapsack, a pail of butter and a hatchet in his hand, and the heavier part of a hundred pound skiff on his shoulders. Four miles and a half of an up hill and exceedingly rough road brought us to the lower Ausable Lake. Here, borrowing a second skiff, we all embarked, with cautious balancing, for a two mile row over a smooth sheet of water, surrounded by scenery of the most imposing grandeur, the like of which is hardly to be found in the wildest parts of New England. The skiffs were left turned upside down on the farther shore, and then another walk of a mile and a half along the stream brought us to the outlet of the upper Ausable Lake. Making smudges, which hardly checked the savage voracity of the flies and mosquitoes, we waited impatiently till the guide had gone to a hut a mile beyond for his gridiron, kettle, and frying pan. Those who had a chance for a fair fight could make out to endure entomological trials; but the one who undertook to find the boiling point of water with the hypsometer when a thousand insects were maliciously waiting to pounce on him at the critical moment of observing the thermometer, did not consider it a pleasant experiment. At length, girding ourselves for a climb over Bartlett Mountain, we had a a chance during the next two hours to test pretty fully the strength of our lungs, ankles, and knees. The four mile tramp to Camp Marcy, by a faint trail leading over mossy stones, tangled roots, and prostrate trees, with our food and blankets to carry, was very much like hard work, but as this was our holiday sport, we tried to make light of it, though with indifferent success. In due time we joyfully greeted the camp, which consisted of some crotched uprights with cross poles that supported one end of some large slabs of arbor vitæ bark, the other ends resting on the ground. Here was a brook of clear

cold water supplied by the Haystack. Here we washed and lunched. Here we piled our packs on the ground and covered them with a large slab of freshly peeled bark. Then, with a few hammers and other slight encumbrances, we were off for the final ascent. From Camp Marcy to the top of Tahawus is hardly a mile, but the rarity of the air was increasing, breathing did not go on unconsciously, and frequent halts were needful, to allow the adjustment of the system to outward circumstances. Still, as compared with the previous march under burdens, the climb was easy and rapid, and at half past four o'clock we were on the highest spot in New York. The thermometer stood at 60° F. Water boiled at 202.5° F.

Who would be so rash as to attempt a description of the soul-expanding scene which here delighted our eyes for an hour and a half, and which will remain in memory a joy forever? Farther on, in the solitary depths of the unlimited forest, lay the Saranac Lakes, invitingly spread out, and the whole view called up for the time each one's latent love of a roving life — but Tahawus was to be the remotest point of our journey. Lake Champlain in the remote distance suggested thoughts of home, and the declining sun recalled the consciousness that the way back to camp could be followed only by daylight. So in jubilant mood we commenced the return by walking, sliding, running, scrambling, leaping on bare rocks and mossy banks, through groves of old fir trees scarcely two feet high, through shallow streams, peat basins, tangled brush, and slippery earth, down the half clad mountain side. Arrived back at the lodging place, the guide, with some help, made a large fire to light up the camp and get ready the supper of broiled mutton, fried mutton, fresh bread, toasted bread, and tea without milk. A few more tender members of the party chose the well ventilated bark shelter and lay rolled in blankets with feet to the fire. The rest, like the guide, scorning luxurious indulgence, spread their ponchos in the open air. A midnight tour of inspection showed the outsiders to be all in the cool enjoyment of a noiseless oblivion, but, somehow, at dawn of day, two or

three were found to have yielded to the attraction of the central fire. At 5.30 A.M., July 8th, the thermometer stood at 42° F. All were up bright and fresh, and with appetites keen for a breakfast with the same sumptuous bill of fare as we had nine hours before. We left Camp Marcy with very light haversacks, but Bartlett Mountain was no tamer than the day before. Near the outlet of the lower Ausable pond we were conducted round to the Rainbow Fall, which comprises several high, slender cataracts of wondrous beauty and wildness. Then it began to rain, and ponchos came in use. After the remaining four mile walk through the wet woods, we arrived back at Mrs. Beede's in a forlorn looking condition, but with merry hearts. After a dinner of civilized life, the wagon in waiting took us back to Elizabethtown. The next day a pleasant ride of eight miles brought us to Westport, with time enough before the arrival of the southward bound steamboat to allow full inspection of an unsuccessful manufactory of steel from iron sponge. This inoperative show of wasted money was well worth seeing, as a palpable illustration of one of those often invented plausibilities which find ready endorsement among men of some experience who ought to know better; and which captivate monied men who are ready to believe that in a new business the ordinary laws of profit and loss do not hold. A charcoal iron furnace, long out of blast, is to be seen on the north side of the bay of Westport, but it did not seem likely to reward us for a long walk that way.

At noon the steamer hove in sight, and we were soon on the way to Ticonderoga. In taking the four mile stage ride from the landing to the higher level of Lake George, we unexpectedly passed a new bloomery forge in full blast, and much regretted that there was not a spare day to allot to this and the iron and plumbago mines on the mountain near by. From the deck of the steamer on Lake George, could be seen the four large circular charcoal kilns which supply fuel for the bloomery. Situated on the lake shore, at the outlet, they are each provided with an inclined track for hauling the floated wood up out

of the water to the top of the kiln. The mountains surrounding Lake George are well wooded, and ought always to be kept so. The lake affords easy transport to the kilns. Hence to the forge is an easy, down hill road, and the falls furnish water for all the needed machinery; so Ticonderoga is a most admirable location for this branch of the iron business. It seems strange, that with all the study and skill that have been brought to bear on the iron manufacture, the best iron should still be economically made by the bloomery forge, which is but a slight modification of the primitive apparatus used centuries ago. But bloomeries are by no means out of date yet. The afternoon sail over the length of Lake George combined recuperative rest with calm, positive enjoyment, and it came in at just the right time of the week to suit our needs. The next morning, instead of waiting at Caldwell for the regular stage, we chartered an ample express wagon to take us earlier to Glen's Falls, so as to have time to see the falls, the limestone formation, the very large saw mills, the paper mill, the marble saws, and some of the many perpetual lime kilns of the Jointa Lime Co. These kilns turn out, from the black stone quarried close at hand, about one hundred and twenty barrels each of very white lime every twenty-four hours, being fired with slabs from the saw mills at the falls. The kilns and store-houses are built all along the canal, so that the chance for shipment is the very best.

Taking the cars a little after eleven o'clock, we arrived in Saratoga at noon, and there stopped over one train to view the Springs, and make a physiological test of the various waters. No positive results, except a few wry faces, followed these deep and frequent potations. After our arrival at Troy, there was still daylight enough left for a visit to Cohoes Falls. At nine o'clock we went to the Bessemer Steel Works, below Troy, to see a "blow" by night. The complete working of one conversion and the beginning of another, finished out for us this long day of sight seeing. The sun had been some time above the horizon when we began work the next forenoon. A due

regard to our financial resources suggested the propriety of a short stay in the city, and West Stockbridge was decided on as our next sleeping place. So the forenoon was spent in a close study of the Bessemer Works, and the rest of the time, before a late dinner, was mostly devoted to the two blast furnaces of the Rensalaer Iron Works, in which they melt a mixture of red hematite from Rome, N. Y., magnetic ore from the Adirondac region, and brown hematite from down the Hudson, with anthracite from Pennsylvania.

Journeying on to Albany, and from Albany to State Line, we sent forward the commissary committee, in a hired wagon with the baggage, to look out for quarters at West Stockbridge. The committee were happily surprised to learn, that, in anticipation of our coming, free accommodations for our whole party had been provided through the generous hospitality of Edward L. Baker, Esq., President of the West Stockbridge Iron Co. We were by no means loth to acquiesce in the arrangement, for Sunday was coming, and what could be better than to have a day of rest among the Berkshire hills? Saturday morning Mr. Bliss, agent of the West Stockbridge Iron Co., was ready to go with us wherever we desired. Making suitable provision for the repair of wasted muscle, we proceeded first to the Leete Ore Bed, a large deposit of carbonate of iron and brown hematite, about a mile and a half from the village. Here we viewed the open workings, and then lighting our candles we went down the shaft and took a long tramp in the several levels underground.

As the Hudson Co.'s extensively worked bed on the other side of the road is but a continuation of the same vein, it did not seem worth the while to go below the surface again, but making an inspection of the upper works, we returned to the weigh-house of the Leete bed, and attended to our midday meal. Taking a look at the rude, but effective, apparatus used for washing dirt from the ore with the water pumped up out of the mine, we went on to the Richmond furnace. Here we found a single blast furnace, in a convenient situation,

together with two round, and four rather odd-looking, conical kilns for making charcoal, and an excellent arrangement of revolving, perforated drums for washing ore. Everything is kept in the best of order, and there is a general appearance of deserved prosperity. The ore bed near by is worked by an open cut, but the mine is inferior to those in West Stockbridge, and most of the ore used at the furnace is brought from those beds. The return did not prove very tiresome, and after tea we took a short evening walk to Truesdell's lime kilns and the quarry from which the limestone is taken. Mr. Truesdell burns in perpetual kilns, with two side fires, using a mixture of wood and Cumberland coal. As the stone approaches white marble in purity, the lime is of excellent quality. A little farther on we came to the anthracite furnace of the Pomeroy Iron Co. in time to see the charge of molten iron tapped off. Night gave a favorable opportunity for seeing the gases burn in the air-heating stoves, and under the boilers.

A quiet rest over Sunday, which began for most of us after sunrise, prepared us for the labors of the coming week. But the heat of the weather on Monday was too intense to allow any very severe effort. We started immediately after breakfast to make a more thorough study of the anthracite furnace in the village. All the minerals collected since leaving Ticonderoga were packed and forwarded to Boston by express. A wagon was secured to take along our luggage and meet us at noon. We commenced the onward march by visiting an old abandoned manganese mine not far from the hotel. Two or three miles farther on is the Cooke bed, which was found, when formerly worked, to yield an ore too rich in phosphorous. But this mine is now being reopened by Mr. Can of New York, in hope of finding better ore lower down. The Steven's bed was next visited, though it has never been opened to any extent; but the ore crops out all along the brook, and this locality illustrates well what surface indications are. Another warm walk of a mile or so, brought us to the main point of interest, the Cheever Ore Bed; and here the wagon was waiting for us

with a welcome lunch. Refreshed by this, we put ourselves under the guidance of the captain of the mine, lighted our candles, and went down vertical ladders seventy feet to the fifth level.

A long walk in this, and another descent of thirty feet, brought us to the lowest of the seven levels. The bed is from four to eight feet thick, and is highly inclined. It is worked by a series of horizontal drifts extending many hundred feet each way from the hoisting shaft. There is a great deal of water to be pumped, and the working is so managed that the water all runs to a well in the lowest level, and is thence forced to the surface. The well will soon be carried down to a ninth level, and while the eighth and ninth drifts are worked, the upper ones will be in process of closing out. After getting some idea of the general character of the mine, and observing the operation of removing the pillars and closing out a level, we remounted by another shaft to the surface. Near by is the Old Hill Bed, which is worked by a very deep open cut. This is really a continuation of the Cheever, and, like that, yields a compact brown hematite of excellent quality. Nowise reluctant to take seats in the wagon, we rode on to the Andrus Bed, an abundant deposit of uncommonly compact ore, which shows at the surface of the ground, and is taken out by an open cut of moderate depth. Though the ore is very hard, and free from intermixture, it is so seamed that no blasting has hitherto been required. And now parting from our kind friend, Mr. Bliss, we resumed our ride, and were soon in Shaker Village, waiting for the cars. Two of us visited the Shaker Ore Bed, near the depot, and found only a large open cut now filled with water. It has not been worked for many years, but there is said to be a prospect of starting it again.

At length the train came along, and a short ride brought us to Pittsfield ready for tea, and a stroll about the town. Hoosac Tunnel was now the great point of attraction, and at a late hour in the evening we took the cars for North Adams, arriving at ten o'clock. Betimes next morning a commodious wagon, with

a stout team, was chartered for the day. Zigzagging up the western side of Hoosac Mountain, with a buoyant appreciation of the glorious prospect, and riding on a mile or two in the elevated valley, we found ourselves alongside the huge pile of stone which indicates the busy location of the central shaft. Without much ado we all entered the iron cage, with a guide, and descended one thousand and thirty feet in less than two minutes. Lighting candles we went on in water ankle deep to the heading, twelve hundred feet westward. When the noise of drilling, the outgushings of compressed air, the shouts of the miners, the dripping of water overhead, the continual foot bath, and the dodging of cars, ceased to be agreeable, we returned, and parting with our very civil guide at some distance east of the shaft bottom, picked our subterranean way, two miles and a half, to the eastern portal, over rough stones and smooth road, wet walking and dry paths, through narrow places and full sized portions, in lonely stretches and spots where busy workmen, with hard drill and powder, were trimming the ragged roof into a smooth arch, among standing cars and moving trains, through various strata of cool, warm, smoky, clear, almost stagnant air. Coming out again into the light of day, we turned into the ravine beside the eastern entrance, and climbed up to the romantic cascades at the confluence of two little streams falling from the mountain above. The next thing was to find the driver, who had gone on above ground to one of the hotels in Florida, and was supposed to have ordered our dinner. A meal of fried trout proved to be the result of this forethought. Riding up the eastern declivity of the mountain, across the depression, and down the panoramic western side, we went to the western shaft and inspected the air condensers and hoisting machinery, and viewed from a safe distance the nitroglycerine manufactory. Then a drive to the western portal and back to the hotel, finished out a well improved day. The evening was very pleasantly spent, by invitation, at the office of the State Engineer, Mr. Frost, who very kindly explained

the peculiarities of the nice underground surveying carried on in connection with the work of the Tunnel.

It was determined to spend the next night in Boston or at home, but by making an early start there would still be time, between two trains, for a visit to the emery mill and mine at Chester. Reluctantly passing by the charcoal iron furnace at Cheshire and the glass works at Berkshire, we reached Chester at ten o'clock. The factory happened to be stopped for lack of water, but there was nevertheless a good chance to see the Blake's crushers, the many sets of steel crushing rolls which need very frequent renewal, the sorting sieves, the washing tubs for removing the soft gangue rock, the driers, the dust floater, the continuous magnetic separators for taking out the iron ore, and the finished products, which are said to be turned out at the rate of three tons per day. Very near the mill is the vein of emery mixed with magnetic iron ore in a gangue of chlorite. It lies almost vertical, and it would be almost impossible to work it were it not for the intermixture of soft rock with the desired mineral. Some of us examined the horizontal drifts carried in at the base of the hill, and those just started higher up the steep hill side. Others improved the spare minutes in culling choice minerals from the rubbish heaps. The number of species found here makes this a delightful place for the mineralogist.

Wednesday evening at six o'clock we separated, to meet again on two subsequent days, for exchanging notes and squaring accounts.

Thus the expedition itself took twenty-three days, and the amount of money spent by each member of the party was about fifty-six dollars. This somewhat exceeded the estimated cost of the trip, but we rode more, and went farther, than was proposed at the outset, and it seemed to be felt by all that the time and money had been well and profitably spent. Work had been assigned to all singly and collectively, each being made in turn chairman of a committee of the whole with a definite subject to report upon. Every one had shown an earnest

disposition to make the most of the opportunities afforded. Perfect harmony prevailed throughout, and we may be sure that the nine young men who could be kept in close and constant intimacy for three weeks, without even a trifling discord, will always look back with unalloyed pleasure to the Adirondac Expedition of 1873.

To the Superintendents of several of the principal railroads in New England we are much indebted for favors in the way of transportation. Beyond these lines there was no way but to pay full fares.

The Professors who went are more than ever impressed with the proved value of such tours, and they would hope that something of the kind may hereafter be carried out every year. Then each student of Mining Engineering will have, during his connection with the Institute, two chances of becoming acquainted with actual mining and smelting. Our experience in this expedition suggests that it may be well to undertake less at a time, and make the time somewhat shorter. In going over much ground rapidly there is little chance to have a full discussion of one object while it is fresh in mind, before proceeding to another. Yearly journeys of moderate extent, rather than less frequent tours embracing a large circuit, seem likely to secure well digested ideas, and those shared by a larger number of students. By shunning expensive hotels and not being over nice about quarters, it may reasonably be expected that, aside from railroad and stage fares, the expenses for each individual could be kept within two dollars a day. This for a trip of fifteen or twenty days taken twice, does not make a large amount, and yet for some students it would be a serious addition to the regular expenses for instruction. We ought to have the means of assisting those in limited circumstances to go on the annual tour of observation.

The proper and timely development of the industrial resources of our country certainly can be insured only by having young men coming forward well trained to fill places where scientific skill is needed. And a little reflection will convince

every friend of sound education that there should be chances given for studying operations as they are carried on in real life. It is clear that no course of instruction can claim a reasonable degree of completeness which does not make provision for rendering the student's knowledge in some measure specific, and thus overcoming the not uncommon repulsion between theory and practice. May we not hope then, that at no distant day, we shall have a special fund yielding interest enough to lighten materially the outlay on the part of each individual, and thus render certain the continuance of these expeditions year by year?

Respectfully yours,

Sept. 2, 1873. JOHN M. ORDWAY.

REPORT UPON THE CHEMICAL LABORATORIES FOR THIRD AND FOURTH YEARS' STUDENTS.

To the President:—

Some improvements in apparatus have been made in the laboratories with a view to increasing the facilities for rapid and effective work; and at present nearly all the conveniences of this kind which are in use in the best schools in Europe, have been introduced, so far as the space and the arrangement of rooms devoted to the chemical department have allowed.

The thirty places in the third year's laboratory have been provided with Bunsen's filter-pumps, at an expense of less than thirty dollars, and it is believed that these contrivances will enable the student to perform a much larger number of analyses than heretofore during the time allotted to the chemical course.

In regard to the practical training of the students, two points have been kept in view.

In the first place, the course in general analysis has been made to cover as wide a field as possible, the analyses being chosen to illustrate general methods, applicable to a number of special cases, so that the experience might serve as a preparation for the ordinary work of an analytical chemist.

In the second place, those students who appeared to have

acquired the necessary skill in the routine work of the laboratory, have been encouraged to investigate unsolved problems in chemistry in order to give them an opportunity to educate their ingenuity, as well as their powers of observation.

The longest course of laboratory work pursued in this country scarcely gives a student sufficient experience to deal with original investigations advantageously, but still something has been accomplished in this direction, and four very creditable papers have been prepared this year for publication in a scientific journal.

Three of these are devoted to the investigation of analytical methods, and announce the discovery of new facts. A fourth deals with an important problem in general chemistry, namely, the direct formation of bodies of the petroleum oil class from their elements without the intervention of coal, or any organic matter, and also makes its contribution of new facts to science.

The professor of analytical chemistry has also prepared a paper for publication, and it is hoped that each year the contributions to chemical science from the Institute of Technology may not be wanting.

The course of study in the theory of chemistry has been carried on this year, as last, with the aid of a German textbook, and the class has acquired considerable familiarity with the language, as well as an acquaintance with chemical facts.

J. M. CRAFTS.

June 16, 1873.

REPORT ON THE INSTRUCTION IN THE DEPARTMENT OF MILITARY SCIENCE AND TACTICS.

To the President: —

In compliance with your request, I have the honor to submit the following brief report upon the instruction in my department during the short portion of the session in which it was under my direction.

Upon assuming charge of the military department in March, 1873, I found that the majority of the students looked upon the instruction as an unmeaning drudgery, and the time devoted to it as nearly wasted. It cannot be surprising, therefore, that comparatively little had been accomplished, and that discipline existed but in name. It has been my aim to impress the students with the idea that the military instruction is given to them, not for the purpose of making them soldiers, but that they may be more efficient citizens, that it is the duty of every citizen to make himself efficient to serve the country as a soldier in case of war, and that they should faithfully attend and receive the military instruction from a sense of duty and honor, rather than from a sense of obligation.

It must be remembered that a mere knowledge of drill is not all the military knowledge which is required to make an efficient officer. He should have a knowledge of discipline, and

the proper mode of maintaining and enforcing it; a knowledge of feeding, clothing, marching and encamping troops; the methods of procuring food, clothing, arms and ammunition, and the mode of preserving and accounting for public property. It was the lack of all this which caused us to lose a greater number of lives by disease, than by the bullet of the enemy, in our late war. The time now allotted to the military instruction is barely sufficient for imparting effective instruction in Infantry drill. The drill tends to improve the carriage of body and general physique of the students, therefore it should not be looked upon as a portion of their mental effort, and counted as such in regulating the mental burden of each student. It should rather be considered as a physical exercise, the tendency of which is mental relaxation. I am desirous of securing an additional hour per week, to be devoted to theoretical instruction in the method of organizing, disciplining and clothing troops; the care and responsibility of public property, and mode of acquiring and accounting for it; the duties in camp, on the march, and in the presence of the enemy, and the general principle of field fortifications, ordinance and gunnery. In short, I would wish to give such instruction as would enable the students to become efficient and capable Captains and Lieutenants of volunteers.

When I assumed charge, the corps of students was armed with muzzle-loading rifles, furnished by the State Government. They were partly uniformed, wearing an unlined blue flannel blouse and a naval cap, with the letters, M. I. T., embroidered thereon. The blouse is unshapely, and affords no protection from cold, being too thin even for under wear during winter. I respectfully recommend the adoption of a uniform of Chasseur cap, blouse and pants of Cadet gray cloth, trimmed with black. The blouse and pants may be procured at a cost of twenty-two dollars and twenty-five cents ($22.25), and are of such material and manufacture as to afford due protection from the weather, and are neat and serviceable as a uniform. From a personal consultation with the students of the present

second year class (then first year), I have ascertained that the feeling in favor of the adoption of a neat and serviceable uniform, such as I have mentioned, is nearly unanimous. If habitually worn by the students when not at drill (and I have reason to believe that many will do so), it will be an economy for them, as it costs much less for the uniform than for a suit of civilian clothes of the same quality of material and manufacture. I most earnestly request that the aforementioned uniform may be adopted, as it is desirable that the students should feel a pride in belonging to the Institute of Technology, and honored in wearing the uniform of its Cadet Corps. It will tend to develope interest in the instruction, and will be of material assistance in raising the tone of the department.

We have received from the U. S. Government for the use of the students, the following Arms and Equipments, viz.: — Two hundred (200) Cadet breech-loading rifles (same size as used at West point); one hundred and fifty (150) sets Infantry equipments; twenty-seven (27) non-commissioned officers' swords, and twenty-seven (27) non-commissioned officers' belts.

Two (2) light six (6) pounders and carriages.

Two (2) cassions and equipments for a section of Light Artillery.

Eight (8) signal kits (complete), including staffs, flags, torches, shades, extinguishers, nippers, wormers, scissors, funnels, canteens, lamp-wicking, matches, and haversacks.

Four (4) telescopes.

Four (4) marine glasses (binocular).

Four (4) manuals of signals.

Two hundred (200) signal code cards.

I respectfully call attention to the necessity of a hall or building in the immediate vicinity of the Institute to be used for drill, and as an armory. Much valuable time is now lost in going to, and coming from, the present hall. A hall or building suitable for this purpose may also be used as a gymnasium. In this connection I may be pardoned for adverting to the importance of introducing a system of obligatory daily gymnastic

exercises in conjunction with the military department. It is neither necessary nor desirable that the students should be made gymnasts, but simply that they should be required to go through a series of daily exercises under the supervision of a physician, or other competent person. The exercises should be comparatively light, and of such a nature as to preclude the possibility of even the weakest student being injured thereby.

The discipline of the Corps of Cadets has improved somewhat since the students have been made to understand that the Cadet officers would be fully supported in the execution of their duty, and that in rendering a prompt obedience to their officers they were not rendering it to the persons, students, but to the authority which they represent, *i. e.*, the Faculty. I have endeavored to establish and maintain, as nearly as the circumstances would admit, the discipline and routine observed in regular service. The trial of a student for "disobedience of orders," and "conduct unbecoming a gentleman," by a court martial composed of his fellow students, has had a beneficial effect upon the tone and discipline of the Corps of Cadets. The system of official correspondence and responsibility for public property involves some extra labor on the part of certain officers and non-commissioned officers. The ordnance and signal property are taken care of and accounted for by two Cadet officers ranking as Second Lieutenants. Other public property is taken care of, and issued upon proper requisition, previously approved by me, by the Quartermaster of the Corps. Invoices and receipts are regularly exchanged whenever public property is transferred. Monthly returns for property received and issued are required from Captains commanding companies, and other officers responsible for public property.

Each commissioned officer responsible for public property is assisted by a non-commissioned officer, who is of a junior class, and selected for his capability to succeed to the office for which he is thus serving an apprenticeship. The Adjutant attends to the duties usually attended to by Adjutants in regular service, *i. e.*, issuing orders, receiving reports and excuses, making de-

tails, and acting at all times as the official organ of the Commandant. He is assisted by a Sergeant-Major, who is selected from the first year's class, with the view of succeeding the Adjutant in the next year. The general rule which should be observed in the appointment and promotion of officers and non-commissioned officers should be, that officers and sergeants should be selected from the second year's class, and corporals from the first year's class. The selection of officers in the succeeding year should then be *first* made from the corporals of the preceding year. As the commissioned officers retain their positions but for a single year, it is a great burden to require them to purchase their swords and belts, and I therefore recommend that these articles be purchased by the Institute, and loaned to the officers, holding them responsible for any damage thereof, other than the ordinary wear and tear. In order to increase still more the dignity and importance of the officers and non-commissioned officers of the Corps of Cadets, and thereby increase the emulation, and inspire the discipline, it would be advisable to issue regular commissions and warrants, as also to enter their names in the printed catalogue of the Institute.

Respectfully submitted,

E. L. ZALINSKI,

1st Lieut., 5th U. S. Art'y.

REPORT UPON THE LOWELL COURSE OF PRACTICAL DESIGN.

On the 7th of October, 1872, the above course was commenced, with eight pupils, none of whom had any idea of the working of patterns, and all were unprepared to "trace" with pencil, or "outline" with the brush — two most important essentials in the work of designing.

The management of *colors* used for making patterns is also a very difficult matter with beginners. After a few weeks of trial, however, a rapid improvement was discovered, and the instructor was gratified to observe that the American youth of both sexes were easily taught, and were quick in comprehending and overcoming these difficulties. In November, the number of students had increased to thirteen, and after January, 1873, the number was twenty-five, all of whom exhibited a great interest in their work, and devoted themselves assiduously to its details. The first object to be attained in this department, or *atelier* of design, was a good execution, and all the energy of the instructor was devoted to this purpose — neatness in execution being a desideratum in designing. The course of study has been the same as that pursued in the *ateliers de dessin* in Paris. These ateliers are the nurseries of designers, who originate patterns for carpets, silks, robes, paper hangings, delaines, prints, etc., and sell them to all the manufacturers of

the world. In these ateliers there are apprentices, composers, and finishers, who produce from year to year, or from season to season, the most novel patterns. The apprentice prepares the colors, and begins to trace and paint patterns. After this, if sufficiently expert, he becomes a finisher, and the finisher completes the pattern which has been composed, and partially painted, by the composer. We believe that the success of the school is due in a great measure to the fact that we have strictly followed the above plan.

The bulk of the work accomplished by the students thus far has been in copying patterns, the few *original* designs executed by them being introductory to next year's work. No instruments are used except the dividers for making the "repeat" and correct distances, and a ruler for lines; all the other portions being strictly "free-hand drawing," and executed with the brush, in color, to give the patterns the same appearance as the calico, delaines, etc., when finished.

The hours of study are daily, from 9 A. M. to 5 P. M. The instructor in this department takes pleasure in stating that his pupils have all shown great application, and constantly increasing interest in their work, and he expresses highest confidence as to the success of making first class designers in this atelier, when so excellent a spirit is evinced among the students, and where so goodly a share of inventive genius is apparent among the American pupils — the girls as well as the boys.

Respectfully submitted,

CHARLES KASTNER.

June 2, 1873.

REPORT UPON THE INSTRUCTION IN PHYSICS IN THE COURSE OF LECTURES.

To the President: —

During the past year the facilities of the lecture-course in Physics have been largely increased in several ways. The printing of a portion of the notes which the classes were formerly obliged to copy from the blackboard, has greatly lessened the drudgery formerly attendant upon the earlier portions of the subject, and a marked improvement has consequently been noticed in the attainments of the classes, as shown by their various examinations, so that at the last annual examination fewer were conditioned in the Physics of the first and second years than has before been the case since the writer assumed the position of lecturer, while the average rank was at the same time proportionally higher.

Another partial change has largely contributed to bring about this desirable result. Instead of devoting half of the hour allotted to the exercise in oral questioning, a method which seems singularly ill-fitted for the thorough examinations of classes as large as those which we now have, the lecture is made to consume a somewhat greater proportion of the time than formerly. An interval of fifteen minutes after the beginning of the exercise is given, during which time the student may copy any

figures which are to be taken from the board, or call for a re-demonstration of any proposition or explanation of any difficult point, which may have suggested itself since the previous lecture. The knowledge of the class is tested by a series of informal written examinations held, on an average, once a fortnight, and usually occupying half an hour. These are substituted for the oral examinations formerly given before every lecture, and as the burden of examining carefully so large a number of papers is so great as to preclude the possibility of doing it so frequently, a portion of the papers — usually about a quarter of the whole number — are examined each time. This system has proved very successful in practice. In addition to this, occasional examinations are held, lasting for one hour. The ranks attained by each student at these times are registered in a book kept for the purpose, and together with the ranks attained at the regular annual and semi-annual examinations, form part of the records of the department.

The student is in no case required to prepare a lesson for recitation. The subject is fully discussed in a lecture, and the important points brought to notice. The first portion of the course, occupying the second half of the first year, is devoted to a thorough discussion of Mechanics, as it is only by a clear understanding of the fundamental principles of force and motion that the student can profitably pursue the latter part of the physical course. The lectures of the second year are devoted to the subjects of Sound, Light, Heat, Magnetism and Electricity. It is always the endeavor to combine the theoretical and the practical as far as possible; to teach the student what physical investigation really is, the care necessary to avoid errors, the corrections to be applied to observed results, and the perseverance without which no research of any value can be conducted. It is hoped that as the number of our students increases, it may be possible to establish additional series of lectures for those taking the course in Science and Literature.

While the mathematical demonstration of physical principles is given whenever practicable, the lectures are very fully illus-

trated by experiments. And as the success of the instruction in elementary physics depends very largely upon the number and quality of the instruments which we possess for the experimental illustration of the lectures, it will be advantageous to speak somewhat at length upon this subject.

It has been the custom of the writer to devote most of his spare time during the winter months of each year to the strengthening of some particular portion of his course of lectures. The principle followed is to plan the apparatus with special reference to the work of the Institute, and, whenever possible, to have it constructed in the building, or at least by workmen under immediate supervision. In this way the collection of apparatus has been largely increased at a comparatively slight expense. There are, however, certain large pieces of apparatus which cannot be constructed to advantage in this manner, and for which a specific appropriation outside of the regular amount allotted to the Physical Department will be needed, unless the necessity is obviated by individual generosity.

During the winter of 1872–73 the subject of Mechanics of Solids was worked up. The apparatus for illustrating this portion of physics was somewhat meagre, but there are now only a few additional pieces of apparatus necessary to render it quite complete. The collection comprises all the instruments necessary for the experimental verification of the laws of oblique and parallel forces, statical moments, centre of gravity, the mechanical powers, laws of motion, pendulum and friction. The subjects of elasticity, mechanics of liquids and mechanics of gases, are less completely illustrated, though the apparatus relating to them is sufficiently extensive for most present purposes.

The acoustic apparatus is exceedingly full, comprising almost all of the more important instruments made by Kœnig, of Paris, the first European constructor, together with many pieces of home manufacture. Besides the large collection presented to the Institute some years since by Mrs. Hemenway, the recent generous gift of Mr. J. C. Hoadley for this specific

purpose has enabled us to obtain from Paris a number of new instruments, among which the following are especially worthy of notice: —

Electric interrupter, with three tuning-forks, designed to keep up a continuous vibration by means of electricity.

Tuning-forks giving 256, 261, 264 double vibrations per second, respectively, being the middle C of the Physical, French and German pitch.

Set of ten steel cylinders, giving tones ranging from 4,096 to 32,768 double vibrations per second, for determining the upper limit of audibility in individual cases.

Kœnig's apparatus for measuring the velocity of sound within small distances; comprising an electric interrupter giving ten vibrations per second, a standard fork, furnished with a mirror, for the accurate adjustment of the interrupter by the optical method, and two electric sounders beating tenths of a second automatically under the influence of the interrupter.

Mach's apparatus for showing that the pitch of the note given by a sounding body is raised when the body is approaching the ear, and lowered when receding from it.

Harmonic flute for determining the velocity of sound in air or gas, by Wertheim's method.

Set of eight closed organ-pipes, comprising the gamut next above middle C.

Discs of brass for sympathetic vibrations of plates.

Apparatus of Count Schaffgotsch for studying singing flames, with whirling jet for repeating the experiment first suggested by Prof. Wm. B. Rogers, showing the alternate extinguishing and relighting of the flame.

Free reed and resonant tubes, for studying the laws of reed pipes.

Two organ-pipes having an interval of a fourth, giving their resultant tone when sounded together; also a large pipe in unison with this resultant tone.

Manometric gas-flame attachment to Kœnig's interference

apparatus, for studying the phenomena of interference of sound by means of the eye.

Crova's apparatus for illustrating by projection the various phenomena of wave motion. This apparatus is furnished with seven glass circular discs, upon which the necessary curves are traced, so that by their revolution before a vertical slit the movements of particles transmitting vibrations are illustrated, thus exhibiting the rationale of the progression of a sonorous wave reflection of an isolated wave, continuous reflection phenomena of organ-pipes, interference, etc.

Besides these the collection comprises several minor pieces of apparatus which have not been mentioned, and also a series of large tin tubes for exhibiting the phenomena of singing flames upon an extensive scale.

In this connection should also be mentioned a valuable set of pipes for illustrating the most important organ stops, presented by Messrs. E. and G. G. Hook and Hastings. The pipes are tuned to the same note, and comprise the Doppel Flute, Harmonic Flute, Flute, Trumpet, Hautboy, Vox Humana, Viola, Viol d'Amour, and other stops, which, together with the various sets of pipes previously belonging to the Institute, are amply sufficient for explaining the practical construction of the organ. It would be a desirable addition to our cabinet if we were to obtain specimens of other instruments used in the orchestra, of which we have several, although our collection is small.

The subject of optics is illustrated by means of the valuable collection of instruments purchased some years since by Prof. Rogers. There are, however, many deficiencies. The apparatus relating to heat is also in an unsatisfactory condition.

The department has received a gift of samples of a number of aniline dyes, for the study of their absorption spectra, from from Messrs. Rumpff & Lutz, of New York, through the kindness of their agents, Messrs. Wm. F. Freeman & Co., of this city.

The most defective portion of the apparatus designed for lecture-room use, is that relating to Electricity and Magnetism,

upon which a considerable sum must be spent in order to make it a fair representation of the present state of electrical science.

Taking into consideration those additional pieces of physical apparatus most needed in the course of lectures upon that subject, our most pressing needs are (1) a new and large air-pump of modern construction, (2) a powerful Ruhmkorff induction coil, (3) an electro-magnet of considerable size, suitable for exhibiting the phenomena of diamagnetism, (4) some form of chronograph. There are constant embarrassments resulting from the absence of these almost indispensable instruments, and it is hoped that some means may be found to remove the deficiency before long, so that the department may be enabled to bring its apparatus to that state of completeness which should characterize the collection of the Institute.

It is also desirable that before the beginning of another year the subject of Photography may receive a more systematic treatment than hitherto. The following is presented as a brief outline of a suitable course.

Introductory lectures, treating of the history of photography, résumé of the chemical and physical principles involved, sketch of the optical portions of photographic apparatus, forms of portrait and other objectives, and preparation of reagents; methods of taking negatives on collodion, both wet and dry, methods of taking positives on collodion, paper, etc.; processes of photographing microscopic and telescopic objects. In addition to these topics the lectures should treat of of carbon-photographs and the modern photo-mechanical processes, the Albertype, Heliotype, and Woodburytype. The department is already in possession of an extensive illustrative collection of prints by these methods, and our thanks are due to Messrs. J. R. Osgood & Co. and the "New England Photo-Plate Printing Co." of Boston, Mr. Rockwood, of New York, and the "American Photo-Relief Co." of Philadelphia, for aid in forming it.

The subject thus discussed should at the same time be taught practically by requiring students to take negatives from appara-

tus, prints, buildings, and other objects, and to make from these positives on both paper and glass. If possible in the time allotted, the dry methods should also be taught. In addition to this, special students in physics should acquire the ability to execute negatives from microscopic objects, and regular students in certain courses might be required to furnish specimens of their work before being graduated by the Institute. If the necessary apparatus could be supplied shortly there is no reason why such a course should not be opened regularly at the beginning of the next school year.

Finally, it should be kept in mind that while our apparatus was never before in so good condition as at present, yet additions are necessary every year in order to keep pace with the advance of science.

All of which is respectfully submitted.

CHARLES R. CROSS,
Assistant Prof. of Physics.

MINING AND METALLURGICAL LABORATORIES.

President J. D. Runkle.

DEAR SIR: —The purpose of these laboratories is to furnish the means of studying experimentally the various processes of ore-dressing and smelting. Ore may here be subjected to the same treatment, and by the same kind of machinery and other appliances as are in use at the best mines and metallurgical works in this and other countries.

This may at first appear to be a strong statement, as such a laboratory might be made to cover acres of ground, and to cost thousands of dollars, if we were to include all the demands made by the immense iron interest of the day. But when viewed from the position which the Institute assumes towards these laboratories, it will be seen to be not only possible but practicable to build and to carry on such an enterprise.

Our aim is to have one representative machine of each class. Thus one automatic hydraulic jigger will serve to illustrate all automatic jiggers used in this country, and abroad, and when this is thoroughly comprehended, the student will be able readily to understand all others. In like manner, one kind of reverberatory furnace for roasting gold and copper ores will, for the present, be made to represent all kinds. Practical instruction in the elements of the subject is to be sought for, rather than the scientific completeness which can only be acquired by following closely all the details in some large smelting establishment. And of course we have neither the time nor the means for imparting all the niceties of every special branch.

In systematizing this department there have been many unavoidable delays, and many difficulties to overcome, some of which will be presently mentioned; but it is fully expected that the laboratory will be in thorough working order for the use of the class in mining during the year 1873–74.

The mining laboratory has, at present, in successful operation, some of the most approved ore-dressing and mill machinery now in use in California and Nevada, for gold and silver ores; consisting of a Blake crusher, a five stamp battery, an amalgamating pan, a separator and concentrator, complete in every respect, and capable of treating half a ton of ore in a day of ten hours; the arrangement of these machines is shown in the accompanying cut. The laboratory also contains a hydraulic-jigger, a Rittinger shaking table, a Whelpley and Storer pulverizer, and a Sturtevant fan-blower; all of which, with the exception of the jigger, are shown in the cut.

New machines and furnaces will be from time to time added, as occasion requires.

The metallurgical laboratory contains (*a*) a cupelling furnace, arranged upon the German plan, capable of cupelling fifty pounds of lead at a time; (*b*), a blast furnace capable of smelting five hundred pounds of copper ore in a day of ten hours, having a cross section of twelve by eighteen inches, and one tuyere in the rear; (*c*), (*d*), roasting and smelting reverberatory furnaces; (*l*), (*l*), (*l*), a forge, anvil, and bellows; (*f*), (*g*), (*h*), (*i*), crucible and muffle assay furnaces; (*k*), a large kettle, which may be used for smelting lead (Parkes' process), or as a large sand bath for chemical purposes. The coal bins are placed under the large mortar.

The experimental work of this laboratory is carried on by the students under the immediate supervision of the professor. When a class of students begins work in the laboratory, each is assigned a sufficient quantity of ore to work upon. He first determines the minerals contained in the ore, samples it, ascertains its value and character by analyses and assays, and makes such other preliminary examinations as may serve to indicate its

a general way the proper method of treatment; and then goes to work on the given quantity, twenty to five hundred pounds, according to the subject, making assays at every step, to ascertain where the loss takes place, and the amount of loss. He also takes account of the amount of power, water, fuel, labor, and chemicals expended, so far as it is practicable to do so.

Such was the plan of 1872–73.

Now it is evident that, in starting a new laboratory of this character, it is by no means easy to settle beforehand the details of a proper course of practical exercises. Our work during the past year has been mainly tentative. We have been trying to discover the best way of giving instruction. It was found that a student, when doing all the work himself, could accomplish but little in the way of obtaining accurate and useful results; for such operations require very much more time than any one would anticipate. Accordingly the following plan has been arranged for the coming year: — a student will receive an ore, examine and prepare it, but at the time when any machine or furnace work is to be done, he will have assistants from his own class, the work to be divided among the assistants, each attending to his assigned part, while the leader exercises a general supervision. At the end of the day each one must hand in a full and carefully written account of his work to the leader, who in turn prepares from these daily statements his final report for presentation to the professor.

By and by another student in turn becomes leader of a party, receiving a new ore to investigate, and so on until each one of the class has learned the duties of workman and superintendent, and the prescribed metallurgical course is ended. It is believed that in thus throwing the whole responsibility of a few simple things on each student, the work will be more thoroughly done, and the reports will be fuller and of far greater value. The student in charge, being free from all details of work, by constantly watching all his men, may be as confident of the correctness of his results as if he had performed all the work himself. The ores will be chosen for the

different students in such a manner that they may represent as large a variety of metallurgical work as possible.

There are no suitable text-books to be found to direct the student in this branch of his studies. "Percey's lead" has been at hand for consultation in respect to experiments on silver and lead. Watt's Dictionary and Kustel's processes of gold and silver extraction, are also used for reference; Plattner's Probirkunst has been used for gold gas-chlorination.

In fact, such is the state of the metallurgical literature, that a large number of expensive books are needed to cover what might be reduced to a tolerably small compass; for instance, the student does not want to know, when smelting lead by the reverberatory furnace, that nine different methods are in use in Germany and England. If at his first glimpse of the subject, he is brought face to face with nine different processes, all of which are nearly identical, he is confused, and fails to see why to choose one over another. He needs to know the principles and details of the processes which are most feasible for this laboratory; and hence, when suitable processes have been selected, it may be best to put them in book form and make a laboratory text expressly for this work. This can hardly be done without the experience of a year or two more.

In this report some reference should be made to the spirit with which students have taken hold of this work. The tone of feeling among them has shown that they have thoroughly appreciated the character, the use, and the demands of these laboratories. All work has been most cordially and carefully done, and it seems well nigh certain that when the resources of the laboratory are developed, which will undoubtedly be accomplished the coming year, the students will reap far more benefit from this course than was at first anticipated, when the difficulties were not only not overcome, but had not yet been discovered.

When preparing a young man for the possibility of filling responsible positions in after life, there seem to be three very important qualities to be developed in him; he needs scientific

attainments, capacity for organizing and directing work, and character or tone. Mere scientific attainments are to be derived more especially from books and lectures, while quick, ready judgment, inventive skill, self-reliance and directive power can be brought out only by practical work, such as the laboratories furnish. The character or tone developed in the student depends in no small degree on the influences around him. When the instructor joins heartily with students in their hard work, and contributes to its full success, the experience of the past warrants us in believing that an earnest, determined enthusiasm will be the prevailing spirit among them. Energetic, persevering effort is best induced by the living example of those who show the power of overcoming difficulties.

During the past year the old arrangement of studies, which was prepared before the laboratory was opened, has been continued; and as this allowed but one or two hours at a time for laboratory work, students have often been obliged to neglect lectures and recitations in order to finish an experiment which lasted a whole day. Thus irregularities were necessitated injurious alike to students and professors. For the coming year a new tabular view of studies has been arranged, which fully admits the demands for time made by metallurgical work. About four weeks during February or March, are set apart for continuous laboratory work, and during that time the student is to have no calls outside to distract his attention from a subject which requires his whole inventive power.

The want of an assistant has been very much felt while getting the work started. Too much manual labor was performed by the Professor while planning his work; he fully appreciates the impossibility of doing hand and head work together, and with this in mind the present system of class instruction has been planned.

An assistant has been appointed for the coming year, and it is hoped that with such aid much more will be accomplished than has hitherto been possible.

A few examples of the work performed during the past year are here cited: —

ILLINOIS LODE, CENTRAL CITY, COLORADO, BY GEORGE PHILLIPPS.

This is essentially an argentiferous gold ore, containing sufficient copper to be worth saving, and a considerable percentage of arsenic and antimony.

The ore was found to contain the following minerals: —

Gold bearing minerals: — Pyrites, gray copper, copper pyrites, zinc blende, galena, and a loose, black substance, which contained copper, sulphur, iron and arsenic, and seemed to be the result of decomposition of gray copper.

Gangue or vein stuff: — Quartz, feldspar, pyrites in grains, carbonate of iron in small crystals.

The ore was easily separated by hand into three lots, gray copper, pyrites, and dust. After being finely pulverized, the whole was roasted, with the exception of 15 lbs. of pyrites. The total weight was 68 lbs., containing 4.7414 grams of gold and 16.305 grams of silver. The pulverized ore was then mixed with coal dust and iron ore and smelted for matt. This matt was again pulverized, roasted and treated with sulphuric acid, which removed the copper as sulphate The copper was precipitated by iron, and then dried and fused in a crucible. This copper was all lost by an accidental crack in the crucible. Some of the silver was undoubtedly carried with the copper as sulphate.

The residue from sulphuric acid was melted with oxide of lead and a little sand, yielding 8 lbs. 7 ozs. of lead carrying silver and gold. This lead, when cupelled, yielded 2.38 grams of gold and 9.40 grams of silver, which were separated from each other by nitric acid. It will be seen that nearly half the gold and silver originally recognized in the ore by assay were lost in the final result. This loss has not been satisfactorily accounted for, from the hasty manner in which the work was done.

COPPER ORE. LAST CHANCE LODE, RAILROAD MINING DISTRICT, NEVADA.

This ore was presented by Mr. J. W. Revere, who superintended the metallurgical work himself.

The ore contained red oxide of copper (cuprite), red oxide of iron (hematite), silicate of zinc (calamine), and a little galena, and also a small percentage of silver.

Two partial analyses were made of a sample of the ore, by Miss E. H. Swallow.

	No. 1.	No. 2.
SiO_2	8.37	8.43
Cu	19.87	20.44
Fe_2O_3	35.50	34.10
	63.74	62.97

The ore, amounting to 656 lbs., was treated in the blast furnace, and with it was used from time to time old copper slag, lime, puddle furnace cinder, and sand, according to the condition of the furnace. Iron pyrites from Strafford, Vt., was also used to prevent the possibility of salamanders of iron forming in the furnace. The amounts used were: —

Copper ore	656 lbs.
Old copper slag	292 "
Puddle slag	91 "
Lime	35 "
Sand	31 "
Pyrites	109 "
Coke	240 "

The yield of crude copper was 67 lbs., and of copper matt 77 lbs. 2 ozs., which, latter, when roasted and smelted with charcoal gave 41 lbs. 8 ozs. of copper, yielding a total of 108 lbs. 8 ozs., which in a partial analysis made by Mr. A. H. Pearson is shown to contain

	No. 1.	No. 2.
Lead	2.32	4.67
Copper	88.70	89.61
Silver	trace	trace

No. 1 is from the 41 lbs. 8 ozs. No. 2 is from the 67 lbs. of copper. The result shows that of the 131.2 lbs. which the ore contained, 108½ lbs. were saved, and 22.7 lbs. were unaccounted for in the yield. This loss results from three causes: — 1, the furnace did not clear itself at the end of the run, a considerable amount of ore was left

mixed with coke and slag; 2, the slag undoubtedly carries as much as ¾ of one per cent. of copper, but the amount has not yet been determined; 3, the loss in handling the matt and copper about the tap hole of the furnace. Of the 20 per cent. of copper 16.5 per cent. was saved.

REFUSE OBTAINED FROM THE CELLAR OF A TYPE FOUNDRY WHICH WAS BURNT OUT DURING THE BOSTON FIRE, NOV., 1872.

An experiment was tried by Mr. A. H. Pearson, with the view to answer two questions:—What amount of type metal the refuse contained, and what was the most feasible method of recovering the metal for the owners of the type foundry.

One hundred and eighty pounds of the refuse, when examined, seemed to contain sand, mortar, bricks, stones, shoe-pegs, charcoal, tacks, nuts, bolts, nails, etc., and type metal in the form it assumed, when, in the melted condition, it dropped into the sand.

At the outset it was evident that a water separation for the sand and metal would be needed.

The refuse was washed by means of a powerful hose, which carried away the lighter material and saved the heavier, and yielded three products:—

(*a.*) Coal, shoe-pegs, etc.
(*b.*) Sand.
(*c.*) Residue.

(*b.*) Sand weighed 100 lbs., and by assay yielded 1.73 per cent., which is probably small enough to reject in a mere temporary operation, like the recovery of metal lost in a fire.

(*a.*) Shoe-pegs, etc., contained no metal.

(*c.*) Residue which contained nearly all the metal was treated on a hydraulic jigger of one-sixteenth inch mesh sieve and yielded,

(*d.*) Skimmings.
(*e.*) Metal.
(*f.*) Siftings.

(*e.*) The metal was melted with charcoal in a large crucible, and yielded 84½ lbs. of good ingot type metal worth 11 cents per lb.

(*d.*) The skimmings weighed 20¼ lbs., and yielded 9.04 per cent.

of metal to assay, or in actual weight about 2 lbs. of metal which was not saved.

(*f.*) Siftings from the last jigger were treated on a thirty-second inch mesh jigger, and yielded three products: —

(*g.*) Skimmings.
(*h.*) Metal.
(*i.*) Siftings.

(*h.*) Metal when fused together gave 13 lbs. 2 ozs. of good ingot.

(*g.*) Skimming, weighed 8 lbs. 2 oz., and contained 19.3 per cent. or about 1 lb. 9 ozs. of metal.

(*i.*) Siftings weighed 8 lbs., and contained 53 per cent. of metal, or a little over 4 lbs.

Summing up the results, we find that the amount of ingot metal obtained was

(*e.*)	Metal	34 lbs. 8 ozs.
(*h.*)	"	13 " 2 "
		47 " 10 "

And that the amount of metal allowed to pass by was

(*b.*)	Sand	1 lb. 11 ozs.
(*d.*)	Skimmings	2 " 0 "
(*g.*)	Skimmings	1 " 9 "
(*i.*)	Siftings	4 " 0 "
		9 " 4 "

The metal in (*i.*) siftings was in good condition to save, and would have been treated on the large scale.

This experiment upon type metal has been introduced into this report to show how certain investigations may be made in these laboratories, as incidental and entirely subservient to the course of instruction.

Respectfully yours,

ROBERT H. RICHARDS,

Professor in charge of Mining and Metallurgical Laboratories.

THE INSTRUCTION IN ARCHITECTURE.

President Runkle:—

Dear Sir: The instruction in the department of Architecture has, during the last year, followed the course laid down in the Catalogue, only differing from the work of the previous year in the organization of an advanced or Post-graduate course of study, in accordance with the recently adopted policy of the school. This has been effected, as was proposed in my last report, by separating from the undergraduate work the subjects of practical construction, specifications, and working drawings which the undergraduates have not time to pursue to advantage. Many of the special students have taken this advanced course in construction in the place of the scientific study of construction with which the regular students are occupied, simultaneously with the undergraduate course of design. The Post-graduate course of Design has not yet been organized.

Three Regular Students, and about twenty Special Students, have been in attendance through the year. Besides the studies strictly belonging to the course, Professor Warren has given the students in architecture special instruction in Descriptive Geometry, and I have myself given them a course of lectures on Perspective and the Perspective of Shadows. Mr. Létang has also given daily instruction in charcoal drawing during a

part of the year. The study of the history of architecture has been pursued more systematically than in previous years, the development of styles from the fifth century before Christ to the reign of Charles the Fifth being followed with a text-book, with lectures and such illustrations as our collections afford. The Trustees of the Boston Athenæum have kindly allowed us to use their excellent library of architectural works to supplement the deficiencies of our own.

The subjects upon which the class of design have been occupied, after the elementary work with which the year opened, are as follows: — 1. A monumental column; 2. An artist's house; 3. A railway station; 4. A monumental chapel; 5. A private museum of painting and sculpture; 6. A campanile; 7. The employment of four columns; 8. A pavilion between two bridges; 9. A village church; 10. A grand staircase under a vaulted ceiling or dome; 11. A Natural History building; 12. A school of chemistry; 13. A military and naval tomb. This last was drawn and designed in perspective.

Most of these works have been photographed on a small scale, as a memento and record of the year's work.

The collections have not been materially increased during the year, but a good deal of work has been done in arranging and cataloguing the books and photographs, and although not increased in numbers they are much more serviceable than they have hitherto been.

I am very truly
Your obedient servant,
WILLIAM R. WARE.

DEPARTMENT OF MECHANICAL ENGINEERING.

President Runkle: —

Dear Sir: The professional instruction in this department is given in four courses: the mathematical, the practical, the graphical and the excursional. To complete the facilities we still greatly need an *experimental laboratory*, especially arranged with reference to this department.

In the first three courses the work is taken up in the same order, as in Professor Rankine's works on "Mills and Millwork," and "Steam Engine and other Prime Movers," which are used as text-books. All these courses are carried on together with the same class; each approaching the same subject from a somewhat different standpoint. In the mathematical course Professor Rankine's demonstrations are usually given; but care is taken to collect from his several books and papers all he has given upon a particular subject, that the simplest as well as fullest discussion may be presented to the class.

In the practical course the entire attention is given to the applications of the theory, as involved in practice. Applications, as far as possible, are made to existing engineering works, and to problems as they occur in practice.

In the graphical course the instruction is chiefly based upon good examples of American practice; and it is intended that

each exercise in theory, or practice, shall be supplemented by a drawing exercise covering the same ground. The subject of gearing happens, just now, to be the subject under discussion in the theoretical and applied courses; and the corresponding graphical work is making working drawings of a pair of bevel gears, designed by James B. Francis, Esq., of Lowell, and which now transmit the power produced by one of the largest turbines in the world. These gears have epicycloidal teeth; and as there are correct and approximate methods of drawing such teeth, students will draw them by different methods, and thus be able, by an actual comparison, to judge of their comparative correctness.

The excursional course is proving a very important one. Once a fortnight, or oftener, visits are made to establishments where machines are in use, or in process of construction. Each student is held responsible for some particular part of a machine or operation, which he must report upon, either in words, or by measurement and sketches. Afterwards a summary of all these reports is made for the benefit of the whole class, and as the basis of such further instruction upon the particular subject under consideration as may be desired. For the present I am indebted to Professor Lanza for valuable aid in the theoretical course, and to Mr. Schubert in the graphical course.

I am aware that a mechanical laboratory was a particular feature in the plan of instruction, as developed by President Rogers; and I beg respectfully to suggest that if we would see this department of the Institute take its proper position, the establishment of such a laboratory should no longer be delayed. After the conferences which I have had with yourself and Prof. Pickering upon this subject, I venture to submit the following outline of a mechanical laboratory, with such details as to use as a machine shop, and as an experimental laboratory, as time would permit.

In the first place this laboratory should be furnished with a certain number of the more important machine tools, and all

the adjuncts necessary to their use. Each student in the department should, early in his professional course, be required to become somewhat familiar with these tools by actual use, that they may afterwards be used to better advantage as models and types in the higher theoretical and practical instruction. If, at the same time, this laboratory should be used for the construction of models to illustrate the instruction in this as well as other departments of the Institute, it would furnish the student an excellent opportunity to see the great difference which often exists between drawings made to illustrate a design, and those which the experienced draughtsman will make for the actual construction of that design, for the purpose of securing the end sought with the least expenditure of materials and labor.

Another important part of the outfit for such a laboratory is the apparatus for making tests of power, efficiency, etc. Engineers are often called upon to make such tests in practice, and it is exceedingly desirable that students should have an opportunity during their professional course, to become acquainted with the means, and have practical experience in making such tests.

Such a laboratory should be supplied with its own steam boiler and engine especially designed and arranged for experiment; then, with thermometers, pyrometers, barometers, an indicator, a transmission dynamometer, an absorption dynamometer, a calorimeter, a chronograph, and apparatus for weighing and measuring, we could perform experiments to determine: — weight of fuel burned; weight of water evaporated; temperature of fire; temperature of escaping gases; waste of fuel in escaping gases; barometric pressure; pressure of steam in boiler; pressure of ste m in cylinder; speed of engine; indicated power of engine; effective power of engine as measured by transmission and absorption dynamometers; value of Joule's equivalent; experiment on safety of boiler; comparative pressure and temperature of steam; latent heat of steam; evaporative power of various fuels; air required for combustion and dilution; distribution of fuel and air; rate of

combustion; heating and cooling of gases and vapors by compression and expansion; proper and improper methods of setting valves; effects produced by superheating and wire-drawing steam; value of wrapping substances, as felts, cements, etc.; effects of steam jackets; efficiency of governors; uniformity or ununiformity of motion of fly-wheels, etc.

Such are some of the many experiments which could be readily performed in the laboratory for the instruction of students. But new questions are constantly arising, and this laboratory should always be prepared for their examination and solution.

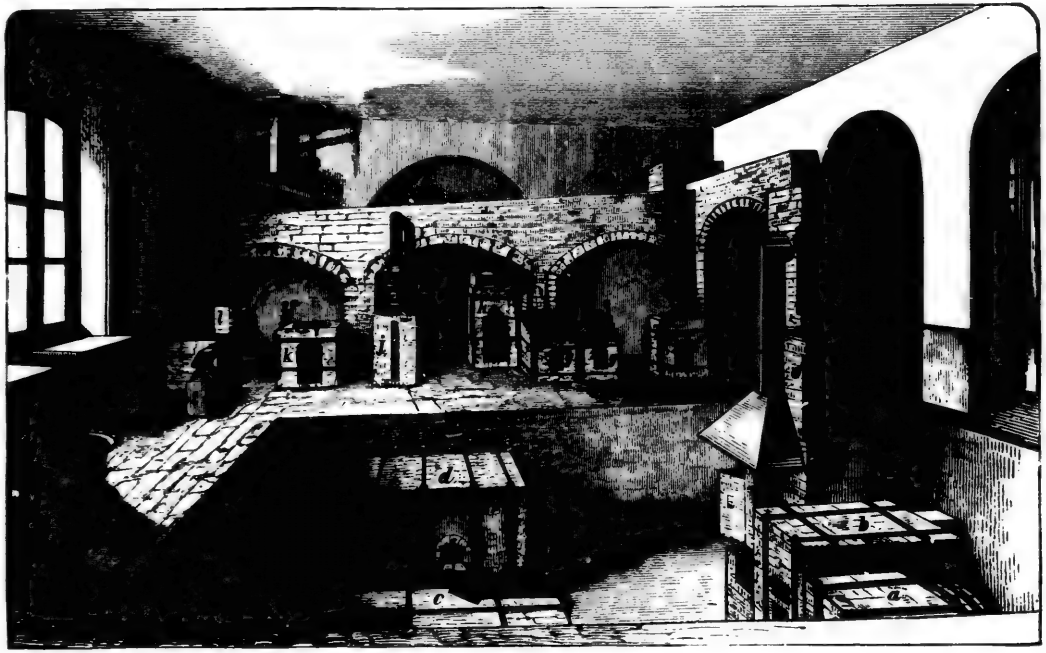
Very respectfully yours,

CHANNING WHITAKER.

Assistant Professor of Mechanical Engineering.

MINING LABORATORY.

MINING LABORATORY.



METALLURGICAL LABORATORY.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

PRESIDENT'S REPORT

FOR THE

Year ending Sept. 30, 1874.

BOSTON:
PRESS OF J. S. CUSHING & CO.
1874.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

PRESIDENT'S REPORT

FOR THE

Year ending Sept. 30, 1874.

BOSTON:
PRESS OF A. A. KINGMAN.
1875.

PRESIDENT'S REPORT.

To the Corporation of the Institute:—

Your attention is respectfully asked to the report of the Secretary, and accompanying documents.

The aggregate attendance for the year was 310, a decrease of 65 from the previous year. This decrease was probably due in great part to three obvious causes: (1), the financial crisis which came upon us so suddenly at the beginning of our year, and almost entirely cut off the usual accession of special and advanced students, who join the school after the opening; (2), the increase of the fees from $150 to $200 per annum, which now first took effect; and (3), the increase in the requisites for admission, the elements of French and solid geometry having been added to the requirements of the preceding year. And while these additional requirements, especially the French, were poorly met, and not rigorously enforced in the admission, it is still certain that they influenced the result. The second cause named is known to have changed the intention of some; but it is very probable that the first cause, and which is still operating, was the most potent of all.

It is well known that the success of the previous year was marred by the crowded state of our building. The size of the lower classes made a division into four sections neces-

sary for the proper instruction in some subjects, which made an additional number of lecture and recitation rooms desirable; and in these respects but little relief has been experienced during the past year. Some relief has been afforded by professors using their private rooms more freely for small classes in their own departments; but I am obliged to again ask your earnest attention to our want of room for the proper development of several departments of the school. Nothing more can be done in our present building for perfecting and expanding the work already entered upon; and particularly in the higher departments of instruction upon which, finally, the real rank of our school must rest. No matter how good the instruction involved in our courses may be, nor how perfect the appliances, we shall bar the way to all high aims and results, if we do not in all possible ways encourage a spirit of investigation, and furnish the amplest opportunities for the most advanced instruction, and particularly for scientific research, the most powerful stimulant for both teacher and taught. It is evident that the proper buildings and equipments cannot be had without a large expenditure, and after they are obtained, cannot be maintained without a large current expense; still, if we would attract the highest grade of students, and especially if we would do all in our power to give the proper rank to industrial education, and thus aid, through research in connection with the higher instruction, and through the thorough training of our graduates, in properly developing the wonderful resources of our country, these expenditures must be met. I hope to be pardoned, if I seem too earnest in again pressing this subject upon your attention; but it cannot be, if the facts in the case were fully known by the public, that there would not be a hearty and generous response. The erection of our proposed Chemical Laboratory building, for which the State has already generously given us a site, would give the needed relief, and would probably be all we should require in the way of buildings for some years to come.

Professor Charles H. Wing, who has charge of the department of Analytical and Organic Chemistry, during the temporary absence of Professor Crafts, says that "the room at the disposal of the department is not sufficient for instruction in Analytical Chemistry, many processes must be omitted for want of suitable arrangements for conducting them with safety, and the Professor has viewed with considerable apprehension certain operations, too important to be omitted, involving, for want of a proper room, some danger to the student and also to the building. But Analysis is the mechanical portion of Chemistry and were instruction to cease there, the student would, on graduating, have neither a knowledge of applied chemistry, nor any idea even of the scientific methods of modern chemists, would only be qualified to do the drudgery, to be the 'hewer of wood and the drawer of water' to the chemist proper. The instruction should go farther than this; and the time now allotted in the revised course for laboratory work and the zeal displayed by the students now in this department will, in the opinion of the writer, render it possible to complete the necessary analytical work during the Third Year, leaving the remaining year to be devoted to the study of practical and scientific chemistry. Omitting any discussion of the wants of the department of applied chemistry, if the erection of the new Chemical Laboratory is to be delayed, there is an almost imperative demand for a building of one story, practically fire-proof, affording to the department of analytical and organic chemistry additional room say 30 x 50 feet, more if practicable, less if needs be, but at all events some room properly fitted for chemical research (and for such operations in analytical chemistry as should not be done in the present laboratories) ready to be occupied at the commencement of the next Collegiate year."

I also ask your attention to the able and interesting statement of Professor Ordway, as an important part of this presentation.

The Courses of Instruction. During the early part of the year much time was devoted to a revision of the courses of instruction. It had become apparent not only that too much was asked of the students in all the courses, but that the amount required in the different ones was quite unequal, as was also the work of the different years in the same course. These difficulties had grown gradually by the addition of new subjects, and also by the desire of each Professor to make his own instruction as complete as possible. A new course in Metallurgy was established for those who found the mathematics of the Course in Mining too difficult, and preferred to devote more time to the chemical side of their profession. To meet the wants of the increasing number of students who do not wish to take any of the strictly professional courses, two new ones, one in Physics, and one in Philosophy, were added, and all of them were made distinct from the beginning of the second year, instead of the third, as heretofore. This extension of the strictly professional studies over three full years will prove of great advantage in all the courses. These revised courses went into operation, with few exceptions, at the middle of the year; and although a few more changes will from time to time be found desirable, yet I think that they have substantially solved the difficulties.

Graduation. The question is sometimes asked why so small a proportion of each class graduates, and whether it is not mainly owing to the fact that the courses are too difficult for the average student?

Year.	Total.	Special Students.	REGULAR STUDENTS.				No. of Graduates.	Percentage.
			1st Year.	2d Year.	3d Year.	4th Year.		
1864-5	27							
1865-6	72	9	35	31				
1866-7	137	27	64	24	22			
1867-8	167	43	56	37	14	17	14	.518
1868-9	174	63	57	23	22	7	5	.156
1869-0	206	54	68	45	24	15	9	.141
1870-1	224	77	72	36	17	21	17	.304
1871-2	264	84	91	39	33	17	11	.198
1872-3	375	140	115	61	27	32	31	.309
1873-4	310	128	68	59	34	21	16	.219

To answer this question properly we should, in the first place, deduct all special students, as is done in the above table. In the second place, we should also deduct those who take all the studies of the first year without the intention of graduating, which is probably not less than twenty-five per cent. of each entering class; but this allowance has not been made in computing the percentages.

It is undoubtedly true that in the past, inadequate preparation, and an over crowding of the courses, have been efficient causes; but they are no longer controling with the majority of students. It quite frequently happens that a good student takes a strong dislike to a particular subject, and prefers to give up his degree rather than to continue it; and another supposes that by dropping some subject, which he regards as not vital, he will be able to do better in the remaining studies, a supposition which is seldom realized. There is, however, a growing desire on the part of students to graduate, and this, with better preparation for admission, and a better adjustment of our work, will from year to year increase the percentage of graduates in each class.

Theses. This is the first year in which the graduates have presented their theses before the final examination, a change which has been found feasible by the relief afforded in the revised courses during the second half of the fourth year. The general excellence of these theses, and the marked ability of several of them, certainly justify the change. Your attention is called to the abstracts on page 81 of this report.

Preparation for Admission. The High Schools and Academies of the country are, in general, becoming from year to year, more distinctly schools of science and the modern languages, and whatever tends to improve them for the education of the large numbers whose school days end with graduation from them, will the better adapt these schools to fit students for admission to the Institute.

We still need a better preparation for admission to be able to do well in four years what seems desirable: and I take this opportunity to respectfully ask the attention of teachers who may be called upon to prepare students for admission to the Institute, to this subject. We now require "arithmetic (including the metric system of weights and measures), and algebra through equations of the second degree, plane and solid geometry, French grammar through regular and irregular verbs,[1] English grammar and composition, rhetoric, (so much as is included in the first part of Bain's Rhetoric, or its equivalent), and geography. In general, the training given at the best High Schools, Academies, and Classical Schools, will be a suitable preparation for this school."

To make more clear what we still wish to accomplish in the near future, I will also quote from the Catalogue the scheme of our First Year's work.

ALL COURSES. — FIRST YEAR.

			No. of Exercises	Hrs. per week
1	Algebra finished	1st half	45	3
	Plane and Solid Geometry reviewed	2d half	15	3
	Plane and Spherical Trigonometry	2d half	30	3
2	General Chemistry	1st half	60	6
	General Chemistry	2d half	30	2
	Qualitative Analysis	2d half	30	4
3	Structure of the Sentence	1st half	30	2
	Rudiments of Logic	2d half	30	2
4	French		90	3
5	Mechanical Drawing and Elements of Descriptive Geometry and Perspective		90	6
6	Free Hand Drawing		90	3
7	Physiology and Hygiene	2d half	30	2
8	Military Science and Tactics		60	2

We will refer to the subjects in the order given in the scheme. In the mathematics, one-third of the time was spent in a review of what was required for admission. This seemed necessary on account of the inequality in the preparation of

[1] "The amount of French at present required is embraced in Part I. of Otto's Grammar, and the first twenty-five pages of Böcher's French Reader, or their equivalent."

different students. In the near future we must ask preparation in logarithms, and a few other subjects in algebra, and plane and spherical trigonometry, which will enable us to complete analytic geometry and calculus by the end of the second year, and thus give two full years for analytic mechanics and applications.

We are not likely to ask any preparation in chemistry for some time to come; and yet every secondary school should have a small and inexpensive chemical laboratory in which the elements of the subject should be thoroughly taught. With such aid we could make our general course in chemistry, which ends with the first year, much more complete.

The preparation in English is defective, not perhaps that the student is ignorant of the facts of history and literature, but because he has neither skill, nor ease, nor even accuracy in the use of the language. The remedy is not in the study of history and literature, but in the study of the structure of the language, and a constant application of the few general principles involved, until they become fixed in the memory and in the habit so firmly as never to be forgotten or disused. An occasional exercise in composition is not sufficient. An exercise in writing, in some form or other, should be the one never to be omitted for a single day, until, first, accuracy, and second, facility of expression, have been acquired. A ready use of the language should be made of the greatest aid in the study of all other subjects. What can be clearly expressed must be clearly thought, and no test is of so much value as a written examination.

In French the preparation was better than in the previous year, but upon the whole, not satisfactory. There will be a gain from year to year, and we wish to increase the amount until we can get about twice as much as is now required. This will enable us to complete the general course in this language at the end of our first year, and give proper time in the following years for German.

Free Hand and Mechanical Drawing and the Elements of Descriptive Geometry will soon be well taught in the best schools, and we shall be relieved of most of our first year's work in these subjects.

Believing that these changes will be for the elevation of all the schools involved, we earnestly ask the aid of our fellow teachers in making them a reality.

Discipline. The discipline consists almost entirely in the examinations, all of which are written. The intermediate examinations are those which are held once in about four weeks and occupy one hour, the time of the ordinary exercises. No time is allowed for preparation for these examinations, nor are they allowed to interfere with the current work in any department. The papers are carefully read and marked on a scale of 100. The marks are recorded, and also communicated to the students for their information and guidance. Besides the above, there are the semi-annual and annual examinations. While these are in progress all the exercises of the school are suspended. The position of the student is determined by these examinations. At the semi-annual examinations the record is, passed, passed with conditions, can continue as a special, and dropped. At the annual examinations the record is, passed, passed with conditions, can continue as a special, must repeat the year, and dropped.

Department of Military Science and Tactics. This department has always labored under two serious difficulties; (1), the want of a fixed policy to guide and limit it, and (2), the want of a suitable hall, conveniently situated, in which to give the practical, and by far the most important part of the instruction.

It ought perhaps to have been expected that a subject, entering so little into the main purposes of the school, would be simply tolerated, rather than welcomed, by both teachers and pu-

pils; and that this want of sympathy should have given rise to more care and anxiety than has been demanded by any other department. On this account, also, there has been a wide diversity of opinion as to the exact place it ought to hold in our scheme, and particularly with what detail and rigor the instruction should be given. These have been the vexed questions upon which the Faculty have year after year deliberated; only to find, that no sooner was one settled, than another equally important in the opinion of some one, would arise to take its place. Thus, year by year, had we approximated towards a practical solution of the problem, when, as you are aware, the whole subject was put into the hands of a special committee whose able report adopted June 16, I include for the information and guidance of all concerned. The conclusions were only reached after a careful consideration of all the questions involved, and with the aid of all the experience which the Faculty could offer; and I believe that the opinion entertained by some, that our school was becoming too military in its character has had no foundation in the past, and will have none in the future, other than that which can be fairly drawn from the facts and conclusions of the report. There has been no intention on the part of any one, so far as I know, or even wish, to give the military element undue prominence and importance, much less to convert our school into a military one.

My only desire has been to make it as efficient and valuable as possible, within the limits assigned to it. This has been simply my duty in the matter, and in short the only course which could prevent the department from becoming a demoralization and disgrace to the Institute.

The want of a suitable hall for drill, which could be reached without loss of time, and without discomfort in bad weather, has been a constant source of trouble and embarrassment to the department. This want was carefully considered by the committee and the plan submitted and adopted as the one, which upon the whole, seemed most feasible to meet the pressing

emergency, was carried out during the summer vacation; and I now have the pleasure of reporting that we have an excellent building 155 feet long by 50 feet in width, and one story in height, covered with corrugated iron and a slated roof, containing a light and well ventilated drill-hall, with ample space for gun-racks, wardrobes for uniforms, and boxes for those who use the gymnasium.

Physiology and Hygiene. A large number of our students live on the lines of the railroads leading into Boston, and find it convenient to remain in town all day. They must therefore either dine in the city or bring a lunch, which for the sake of economy is done by the larger number. The result is that these students remain in the building all day, and seldom take the proper exercise, and in bad weather none, except what is got in travelling to and from their rooms, or homes. This want of exercise and a proper midday meal, taken at the right time and under favorable conditions, is having effect upon the health of our students, and is a much more serious matter than hard study. Where the health of one student is injured simply by over study, the health of many is injured by want of exercise, or other preventable causes, while over study is usually the only cause assigned. It is true that each class hears an excellent course of lectures on Physiology and Hygiene, but it is to be feared that too few make a personal application of what is taught them, and thus fail to gain what this instruction is mainly intended to impart. I am deeply impressed with the conviction that a radical change in this department is necessary, and that the laboratory system is quite as important in this as in other departments of the school. To make the instruction of the greatest value to each student it must be applied practically in each case; and while I am not now prepared to advocate a compulsory system of gymnastics, I am satisfied that incalculable good would come from a more personal application of the instruction, with opportunities for

systematic exercise under the direction, not of a mere gymnast, but of a physician who had made this application a matter of special study. If our students lived in dormitories, as at most colleges, or so near each other that their spare time could be spent in out-door athletic sports, the case would be somewhat different; but there is probably hardly another school in the country where the students are so thoroughly scattered, and such exercise had, if at all, at so great disadvantage.

Our only remedy therefore, in addition to what is afforded by the drill to only a portion of our students, is a gymnasium. I take advantage of the delay in the issue of this report to briefly indicate what has been already done in this direction. When the drill-hall was finished we took immediate steps to fit it as a gymnasium. The apparatus which could be best placed against the wall is fixed; but that occupying the central portions of the hall is so arranged, that it can readily be raised a sufficient height from the floor as not to interfere with the drill. By this means the hall has been made equally available for both uses. This gymnasium is open to all the students from early morning till 9 o'clock in the evening. We have also availed ourselves of the opportunity which the drill-hall has afforded us to establish, by way of experiment, a *lunch room*, where professors and students and their friends can get a well-cooked and well-served dinner or lunch, as desired, at a very reasonable cost; so reasonable as to induce those who have depended upon a cold lunch to do so no longer. Dinners, or lunches, are served from 12-30 to 3 P. M., during which time all can be accommodated. Dinners consisting of soup, fish, meat or poultry, dessert, and a cup of tea or coffee, is served for 35 cents, and a lunch at a correspondingly low rate.

In this matter the Institute assumes no responsibility or expense, except that no charge is made for rent or for fuel used in cooking. We fix the prices charged; and the quality of the food, the cooking, and the manner of serving, must be satisfactory to us. In spite of the imperfect conveniences, the ex-

periment thus far has been unexpectedly successful; and if it shall continue equally so in the future, it will be desirable to provide better accommodations, which can readily be done at a very small expense. Then good board can be obtained at from three dollars to three and one-half a week. I trust that those members of the Corporation who have not already done so, will make a personal examination of this matter, and thus be able the better to judge of its importance and bearing upon the welfare of the school.

I cannot close without acknowledging the energy and zeal of Lieut. Zalinski in the erection of the drill-hall, and his valuable service in equipping the gymnasium, and superintending the lunch room experiment.

Lowell School of Industrial Design. In my last report a pretty full account of the establishment of this important department was given, with such indications of success as so short an experiment seemed to justify. Although a good proportion of the students of the First Year returned, it was by no means sure that their zeal and perseverance would not flag before they were at all qualified to enter upon their professional work with a fair prospect of success. But the results of the Second Year have fully realized all reasonable expectations, as I think the facts set forth in Mr. Kastner's report show. In another year some of the students will probably complete the prescribed course and be entitled to the proper diploma, or certificate of proficiency.

The Zoological and Palæontological Laboratory. This laboratory has been fitted up in the building of the Boston Society of Natural History for the joint use of the Society and the Institute. Here Professor Hyatt gives his instruction in Palæontology, and also his course in Comparative Zoology, in the third year, and the laboratory work of the fourth year to students in the course of Natural History. This gives the best

possible opportunity for the convenient and proper use of the valuable collections and library of the Society, under the direction and care of the Society's own Custodian. In this way is the Society aiding to place within reach of all the amplest facilities for study in all departments of Natural History.

Department of Mining Engineering. On the first of January, 1874, after nearly five years of efficient service as Professor of Mining Engineering, Professor Rockwell resigned his professorship to accept the responsible position of Fire Commissioner o the City of Boston. The duties of the Chair were divided between Professors Ordway, Hunt and Richards, and we were particularly fortunate in being able to have the instruction continued without a break by Professor Rockwell's associates in the department. The mining laboratory has been improved during the year by the addition of such machines as were found necessary to carry on the required work.

Department of Architecture. The work in this department is now arranged in two courses; one of four years for regular students, leading to the degree of Bachelor of Science; and the other of two years for special students which includes all the drawing and architectural instruction of the longer course. For admission to this special course no examination is required; the applicant must be sixteen years of age, and if he wishes to take additional studies, must be examined if the subjects require it. This shorter course is arranged for those whose time and means are limited.

Department of Mechanical Engineering. In my last report Professor Whittaker gave the plan of the kind of laboratory which it was thought desirable to build up to aid in the instruction in this department, and also adapted to the solution of any new problems which might arise in relation to steam and power, and such other questions as are involved in their use. I have

now great pleasure in calling your attention to Professor Whittaker's report showing what has been done during the year towards carrying out the proposed plan. This marked and substantial progress is mainly due to the timely aid of Mr. George B. Dixwell, who has not only furnished us with a large part of the means, but what is far more important, has set us a definite problem of the highest scientific as well as practical importance to solve, thus imposing conditions of a very high order, and at the same time aiding us with the knowledge and experience gained by years of study and reflection upon the nature of steam. It is difficult to conceive of a more fortunate combination of circumstances, and at the same time used to better advantage than they have been by Professor Whittaker; and it is my pleasure as well as duty to testify to his zeal and ability in carrying out his plans, regardless of all personal sacrifices. The interest of the students of this department in this laboratory has been so marked, and their aid so valuable as to be entitled to special mention and commendation. We still need, to make this laboratory as complete as possible with the space at our disposal, a few of the most approved machine tools, and whatever else may be necessary to furnish a small shop.

The Society of Arts. This important department merits more attention from the Corporation. The meetings for the year have been fairly well attended, and the communications have been of more than common interest and value. The Secretary has given a fuller report than usual, which is an improvement over the very condensed abstracts of previous years. The value of the report would be increased by a still more liberal summary of the records; but this cannot take the place of a monthly bulletin in which a full record of the meetings can be given. This form of publication, more full and frequent than the annual report, and more permanent and convenient than any newspaper report, however good, can be, would increase the interest in the meetings and improve the value of the com-

munications, because much more care would be taken in their preparation.

Again, the Society needs better facilities for exhibiting in operation the various kinds of machinery, subjects of interest and instruction to all. The extension of our laboratories will in time furnish to the members better opportunities for experimental researches than we can now offer, and add very much to its effectiveness as a Society of the Industrial Arts. Your attention is respectfully asked to these considerations.

Department of Civil and Topographical Engineering. The instruction in this department has been continued substantially as in past years, except that more attention has been given to the practical details of bridge construction. In this subject, as also in hydraulics, and particularly in water-supply and drainage, there is need of fuller instruction in the practice, that the graduates in the department may be as well qualified to enter upon these subjects as they are upon railroad construction. The subjects of water-supply and drainage are rapidly growing into prime importance, and it is extremely desirable that the students should have the advantage of the widest and best experience which can be obtained. If the instruction as now given could be supplemented by courses of not more than thirty lectures each, on bridge construction, and water-supply and drainage, to be given on alternate years to students of the third and fourth years, by an engineer of large experience, and illustrated by some of the excellent examples to be found in the vicinity of Boston, nothing more would be desired. This addition would not overburden the course, nor add largely to the expense of the department; nor would it be difficult to find one among the many able and experienced engineers of this city, who would undertake to give this instruction.

On May 30, 1864, the Committee on Instruction reported through its chairman, President Rogers, the "Scope and Plan of the School of Industrial Science of the Institute," in which

it was proposed to establish laboratories for instruction and research in several of the leading departments. In order that we may readily compare what we have been able to accomplish during the past ten years towards realizing the proposed plans, I quote from the report the part relating to this subject.

"The laboratory arrangements of the school are designed, when complete, to embrace the following departments: —

1. A Laboratory of PHYSICS AND MECHANICS.
2. A Laboratory of GENERAL CHEMICAL ANALYSIS AND MANIPULATION.
3. A Laboratory for METALLURGY AND MINING.
4. A Laboratory for INDUSTRIAL CHEMISTRY.

While intended primarily for the instruction of the students, these laboratories will be used for the prosecution of experiments and investigations on subjects referred to them by the Committee of the Museum or the several Committees of Arts, including the examination and testing of new machines and processes, and the conducting of original researches in the different departments of applied science; and in these critical studies and experiments the advanced students may, when expedient, be permitted to assist.

Laboratory of Physics and Mechanics.

In this laboratory, it is proposed to provide implements and apparatus with which the student may be exercised in a variety of mechanical and physical processes and experiments. Thus he may learn practically the methods of estimating motors and machines by the dynamometer, of experimenting on the flow of water and air or other gases, and of testing the strength of the materials used in construction. He may become familiar with the adjustments and applications of the microscope; be practised in observing with the barometer, thermometer, and hygrometer; and, in a room fitted up for photometry, may learn the mode of measuring the light produced by gas and other sources

of illumination, and the value of different kinds of burners, lamps, and their appendages.

Laboratory for General Chemical Analysis.

In this laboratory, provision will be made for a complete and comprehensive course of instruction in qualitative and quantitative analysis,—embracing organic as well as inorganic substances,—and blending lectures with the systematic practice of the laboratory.

Students proposing to take the course will be expected either to have passed through the first two years' teachings of the Institute, or to be possessed of such knowledge of general chemistry and physics as these preliminary studies are intended to impart.

Besides this general and extended course, it is proposed to have certain partial courses, in which students having a special object in view may obtain instruction of a specific kind, without going through the entire range of laboratory training. Such would be,—

1. Exercises in Organic Analysis.
2. Exercises in Blowpipe Testing.
3. Household and Commercial Analyses, including the Testing of Waters, Detection of Adulterations in Food, &c., Alkalimetry, Acidimetry.
4. Chemical Toxicology, Detection of Arsenic and other Poisons.

Laboratory for Mining and Metallurgy.

Connected with the general laboratory, but forming a distinct department, will be a laboratory of mining and metallurgy, designed for special instruction in whatever relates to practical mineralogy, the chemical valuation of ores, and the operations of smelting and other processes for the separation and refining of metals.

In this department students already trained to some extent in analytical processes will be exercised in the examination and discrimination of rocks and minerals by mechanical and chemi-

cal tests, including a course of practice with the blow-pipe; and will be taught the several methods of assaying the ores and alloys of copper, iron, lead, silver, and other useful metals, as well by the dry as the wet method; of analyzing the fluxes used in the smelting furnace, and the slags resulting from the blast; and of determining the combustible value of the mineral or other fuel with which furnaces are supplied.

In aid of these instructions, the student will have the opportunity of studying the models of mines, and of mining and metallurgical implements and machinery and the collections of rocks fossils, minerals, and ores, with their manufactured products, provided and arranged specially to facilitate his studies in this department.

Laboratory for Industrial Chemistry.

It is further proposed to connect with the general laboratory a department of industrial chemistry, where students may have an opportunity of becoming practically familiar with the materials, implements, and processes of the more important chemical arts and manufactures.

In this department will be provided a collection of dye-stuffs, mordants, discharges, and other substances used in the operations of dyeing, color printing, and bleaching; together with such apparatus as may be necessary, on a small scale, to exemplify these several processes as in actual use.

Here the student will have access to suites of specimens, embracing the crude materials and products of the glass and pottery, and brick and tile manufactures, the different soaps, soda ash, bleaching salts, acids, saline products, lakes, pigments, inks, cements, tanning substances, and other materials and products of the chemical arts; and will be provided with facilities for studying practically the re-actions and processes connected with their use and manufacture.

Provision will also be made in this laboratory for the practical illustration of the chemical modes of engraving and lithography, and for exhibiting the various methods and

processes of electro-metallurgy as applied to silvering, gilding, and the deposition of copper and brass."

It will be observed that two objects were contemplated in the establishment of these laboratories; first, the instruction of the students as a part of their general education, and second, to afford opportunities for investigation in special subjects, in which competent students might participate, or even conduct the research under proper direction and supervision. Thus far our means and energies have been mainly expended in providing for the instruction, the provision for special investigation being incidental, and limited to such inadequate space and resources as are at present at our disposal. We are now, however, the better prepared by the experience of the past years, to enter upon this wider field, and can but hope that the near future will provide the means to attain this most desirable end. When this is done we shall be much better prepared than now, in some important particulars, to attract graduates of our own and other institutions to us for advanced and more comprehensive courses of study.

Railroad Fares. The average age of students entering the Institute has gradually increased with the increase in the requirements for admission. On this account the number of those living on the lines of the railroads, and coming within the rule of half fare while under eighteen years of age, has been growing relatively less. I have now the pleasure to report that during the year, at my solicitation, all the roads, with a single exception, have abolished the rule and now carry all our students without reference to age at the reduced rates. For this important reduction in the expense of a large number of our students the thanks of the Corporation of the Institute are due.

In closing this summary of our very satisfactory year's work, I must recognize two important conditions as always largely influencing the amount and quality of the instruction. The

first is found in the fact that so many of our students come to the Institute from choice, with a more or less well defined purpose as to the preparation they desire for the duties of active life, and are not sent by parents or guardians against their wishes. This indicates a maturity of character and a seriousness of purpose, upon which we have found it entirely safe to rely in all our dealings with our students. We grant, that in the above respects they are men, and not boys, and our discipline is shaped in accordance with this fact. We insist upon respectful conduct, and entire honesty in all examinations and other exercises, and the least infr[illegible] these general rules makes it undesirable to continue the [illegible]ent's connection with the school. Instances where such discipline is needed are exceedingly rare, and made so, mainly, by the spirit which prevails among the students in relation to the causes of it.

The other condition is found in the devotion of all the teachers to the interests of the school. That all should conscientiously perform all assumed duties is expected and requires no special remark; but in the building up of laboratories, and best adapting them to the purposes of instruction, particularly in departments where there was little or no experience to guide, there was needed knowledge, and energy, and above all patience and faith. So many of our Professors have commanded success by the devotion of all their time and energies, and in addition, by contributing liberally of their private means, that the fact is worthy of special mention and recognition.

Deeply grateful for the measure of success which has rewarded the labors of the year, I close this report,

J. D. RUNKLE, *President.*

SECRETARY'S REPORT: 1873-74.

There have been during the year eleven meetings of the Society of Arts, at which the average attendance was seventy-five.

Nov. 13, 1873. Mr. Frederic Ransome, of England, read a paper, illustrated by specimens, experiments, and diagrams, on "Discoveries in the Manufacture and Uses of Artificial Stone," with special reference to the process which bears his name.

Of the processes, his was one of the earliest and most successful, he having commenced his experiments more than thirty years ago, with hard silicious sands and cements of various kinds under great pressure. These proving unsatisfactory, he employed with the same sands a concentrated solution of soda or potash in the form of a silicate. With silicate of soda as a liquid, he mixed chloride of calcium in solution, and produced a stone of flinty hardness, which he could mould into any form; the silicate of lime thus formed in the stone is practically indestructible in the air, and the chloride of sodium is removed by washing. With silicate of potash a firm stone is made, disintegrating under the influence of heat, the soda stone being affected by moisture. The setting takes place quite rapidly, and the insolubility is in proportion to the amount of silica.

The experiments of Mr. Ransome fully proved, in opposition to the statements of chemists, that the silicate of lime thus formed was a permanent stone. It has been subjected to the extremes of heat and cold, with sudden transition from one to the other, to acids, and to various gases, with no effect on its

structure. Being nearly all silica, it is practically indestructible; having no oxidizable constituent, it is unalterable in the air; being impermeable to moisture, it cannot be injured by frost. It may be used for any purposes of construction or architectural ornament that natural stone can be employed for. It has been used for twelve years in Europe, and for some time in Chicago and San Francisco.

His latest form, called *apœnite*, grows stronger with age, may take any color by the use of metallic oxides, and may be made almost anywhere, as the materials are very common, thus saving the expense of transportation.

Prof. T. Sterry Hunt followed in some remarks, showing how this method imitates processes of nature on a grand and beneficent scale.

Prof. Ordway made some further practical statements on the composition and uses of water-glass and hydraulic cement, both involving some of the principles of Mr. Ransome's process.

An automatic Elevator Brake was also exhibited at this meeting.

Dec. 11. Mr. J. P. Putnam exhibited his invention for lighting gas by frictional electricity, by the simple turning of the gas cock, avoiding the danger and the trouble of the use of matches. No perishable material is used, brass and ebonite, or hard rubber, being the principal ones. The apparatus was tested several times before the meeting, and it was as certain in its action as it was simple and durable in its construction.

Mr. Horace McMurtrie read a paper, with illustrations, on "Sectional Boilers," and especially on the form known as the "Wiegand Boiler"; he described also the "Miller or American," and the "Exeter" boilers, — all of cast iron, which is claimed to be the best conductor of heat, and the safest material to guard against destructive explosions. All such boilers are open to the objections of many joints exposed to the direct action of the fire; of unequal expansion and contraction; of insufficient circulation from the divided state of the water; and of inaccessibility for purposes of examination, repairs and clean-

ing; each joint is an element of weakness, and the system of hanging tubes is disapproved by many engineers.

Jan. 8, 1874. Mr. Samuel Batchelder, of Cambridge, presented a dynamometer of his invention, with a detailed description of the same. It is applicable both to steam and water power, for heavy or light machinery, and affords the means for accurate measure of power exerted.

Prof. Whitaker then read a paper on shafting as a means of distributing power, alluding to some of the old-fashioned methods of shafting mills, some deviations from these methods in use, and others contemplated. Without wishing to condemn the prevalent use of light, rapidly-rotating shafting, he stated, that, though this appears to consume much less power than heavier shafting, the difference is far less than is generally believed; the gain, he thought, was more in the use of better materials, more careful workmanship, and more perfect lubrication, than in the increased speed of the lighter shafting.

Jan. 22. Mr. Albert K. Mansfield, of Lowell, made a communication on the "Theory of Turbines," passing in review the four principal methods of converting the power of water in motion into useful effects, viz.: 1, by *impact*; or allowing the water to impinge on planes, or floats in motion, set at right angles, or nearly so, to the direction of the flow; 2, by *pressure*; the water pressing on the floats in motion, but so confined as to move no faster than these; 3, by *reaction*; of the water flowing from orifices against their walls; 4, by *deviation*; of the water from the direction in which it tends to flow, according to the principle that a body resists deviation from straight line motion. The action of water in wheels is often a combination of two or more of these methods. He gave the theoretical formulæ in each of these cases.

Prof. Whitaker drew attention to the indefinite way in which the word *theory* is used, as distinguished from *practice*. The popular, and a very mischievous, belief is that practice is opposed to theory; practice may be opposed to *hypothesis*, which many mistake for *theory*. Theory, in its true sense, means the

whole theory of a scientific problem, all disturbing elements having been considered, and thus is the same as practice. When an incomplete theory is under discussion, its incompleteness should be stated, and then we should hear no more of the supposed, but really non-existent, antagonism between theory and practice.

Feb. 12. Mr. David Renshaw described from a model a new form of sectional boiler, of his invention, which had been in successful operation for several months in Hingham, Mass.

The material is cast iron, and the form that of the reverberatory furnace. This form secures the hottest part in the crown or arch, and by a gradual increase from below upward; the boiler is of a corresponding form, being in its outer portion a true half circle, giving the reverberatory form of furnace and drop flues; all the fire surfaces are directly over the grate, and are very large. The circulation is rapid, and cleaning easy; none of the joints, always a fruitful source of trouble in sectional boilers, come in contact with the direct action of the fire; they are very few, and very accessible. His plan retains the colder, heavier water in the lower portion of the boiler, where it ought to be — a great security against explosion from sudden rise of pressure.

Feb. 26. Mr. Horace McMurtrie read a paper on "Boiler Explosions no Mystery" — being a careful review of the facts presented in the Report of the "Hartford Steam Boiler Insurance Company."

He alluded to the well known causes, of defective materials, faulty construction and form, and especially the ignorance and carelessness of those having charge of boilers. Improper riveting and insufficient bracing, safety valves overweighted or corroded in their seats, inaccurate steam and water gauges, defective setting, inattention to the supply of water, neglect of inspection, were in turn taken up. He gave the record of nearly 12,000 defects discovered in a single year by the inspectors, from the examination of a very small proportion of the boilers in the United States, and of these nearly 2900 were dangerous.

He thought the mystery was that, under the circumstances, more boilers did not explode.

March 12. Mr. J. R. Robinson read a paper, in answer to Mr. McMurtrie, admitting the facts stated, but citing numerous cases which had come under his official investigation, where the explosion of boilers could not be accounted for by any of the conditions above named. He believed that there was a mystery in the causes of these explosions, and that the only safe way was to investigate this mystery, so important for the users of steam.

March 26. Mr. Stephen M. Allen read a paper on "Light and Heat, and their relation to Steam."

Mr. Guthrie made a communication on the Morton Ejector Condenser, explaining its construction by diagrams. This condenser dispenses with the air pump; the exhaust steam escaping from the cylinder is so directed as to unite in a jet with the injection condensing water, by which it is condensed — having first, however, imparted a sufficient velocity to the combined jet, to enable this to issue direct into the atmosphere in a continuous impulsive stream; the contents of the condenser, both water and air, are thus ejected without the use of the pump, and without impairing the vacuum maintained in the condenser.

An interesting discussion took place on various points suggested by this communication.

April 9. Prof. A. Graham Bell occupied the evening in remarks on "Visible Speech," or the "Science of Universal Alphabetics," a system invented in 1864 by his father, Prof. A. Melville Bell.

In this system sounds are represented by symbols indicating the positions of the vocal organs assumed during their production. These may be arranged in a linear series, like letters, forming an alphabet capable of representing the sounds of all languages — a system of universal alphabetics.

He illustrated its application in teaching the deaf to speak. In the deaf the vocal organs are perfect, and the deaf have

hitherto been dumb simply because they cannot hear and imitate sounds, and because the concealed mechanism of speech cannot be seen. By his system the deaf can see how to place the tongue, lips, etc., for the production of every sound, and thus to speak. The system was first introduced in England in 1869, and in America, in Boston, in 1871; it has been attended with remarkable success, and is now extensively used in this country for the education of the deaf and dumb, a class fortunately now not neccessarily dumb because they are deaf.

Its value was demonstrated to the audience by several pupils of his. The system is now adopted by the Boston University.

May 14. Mr. A. C. Cary, of Malden, made a communication on a process, invented by himself, of weaving on a rotary loom. It both knits and weaves at the same time, making a very strong, non-elastic cloth, of any desired width, a yard a minute, and at a very cheap rate. Specimens of this fabric were exhibited.

Mr. E. H. Hewins then read a paper on some of the principal points of difference between the American and European systems of iron bridge building, in which he gave his reasons for preferring the former.

May 28. Mr. Robert B. Forbes read a communication on the best means for preventing collisions at sea, and of strenghtening vessels.

The importance of the so-called Maury lanes, now adopted by the Cunard Company, was dwelt upon. The necessity of the adoption of some such plan has been demonstrated by a series of recent terrible disasters.

He advocated the frequent use of the steam whistle in a fog, sounded so as to indicate the general course of the ship. He dwelt also on the necessity of having ships with double bottoms, without openings between engine room and fire room, or between coal holds and fire room, except in the last by some sort of elevator to carry the coal over the load line into the receiver, near the furnaces.

Mr. C. W. Hinman, a graduate of the Institute, and now "State Inspector of Gas," made a communication on "Gas Analysis."

After giving a history of the apparatus and processes employed by Lavoisier, Bunsen, Regnault, Williamson, and Russell, he explained his own in detail. His process is much simpler than any others in use.

Mr. C. A. Morey, a pupil of the Institute, described the various methods of rendering sounds visible, and gave the results of an extensive series of experiments made by him the past winter with the "Phonautograph" — modified and improved by himself. The curves made by the style set in motion by the vibrations of the membrane of the instrument, were exhibited, highly magnified, by the oxy-hydrogen lamp.

There have been elected during the year eight associate members. Seven associate members have died during the year viz: Messrs. Copeland, Derby, F. H. Jackson, Jewett, Reed, Sweetser, and Thompson; five have resigned, and fourteen have been dropped for non-payment of fees. The list now comprises 297 members.

The attendance at the School of Industrial Science for the year, has been 310; as follows: Resident Graduates, 2; Regular Students of 4th year, 21; of 3d, 34; of 2d, 59; of 1st, 68: Students not Candidates for a Degree and Special Students; 4th year, 13; 3d, 27; 2d, 25; 1st, 35; Students in Practical Design, 26, of whom 15 were females. Of these, as in former years, nearly five-sixths are from Massachusetts, principally from Boston and vicinity; from other New England States, 17; viz: from Maine, 5; New Hampshire, 5; Vermont, 3; Rhode Island, 3; Connecticut 1. From other States there are from New York, 7; Ohio, 8; Pennsylvania and Illinois, each 5; Minnesota and Western Islands, each 3; Indiana, Kentucky and California, each 2; New Jersey, Maryland, Kansas, Missouri, Nebraska, Colorado, British Provinces, Japan, and the Sandwich Islands, one each.

Thirty-eight professors and teachers have been connected

with the school, and several advanced students have rendered assistance in the laboratories, drawing, and surveying. The fees from students have been over $50,000, considerably more than last year.

The School of Design continues to be a successful department of the School, and the report of the teacher in charge will show the artistic and pecuniary value of the work done.

The Lowell Courses this year have been as follows:

Logic: An Examination of the System of J. S. Mill. Eighteen lectures on Monday and Friday evenings, at 7½ o'clock, beginning November 17, by Prof. Howison.

Sound. Eighteen lectures, illustrated by a full series of experiments, on Wednesday and Saturday afternoons, at 3 o'clock, beginning January 7, by Prof. Cross.

Machine Drawing for advanced students. Twenty-four exercises, of two hours each, on Tuesday and Friday evenings, at 7½ o'clock beginning November 18, by Instructor Schubert.

Elementary Descriptive Geometry. Eighteen lectures on Monday and Thursday evenings, at 7½ o'clock, beginning November 17, by Prof. Lanza.

Chemistry: Qualitative Analysis. Twenty-four laboratory exercises on Wednesday and Saturday afternoons, at 2½ o'clock, beginning Feb. 11, by Prof. Nichols.

Architectural History and Design. Eighteen lectures on Wednesday evenings, at 7½ o'clock, beginning December 3, by Prof. Ware.

Elementary German, Eighteen lessons on Monday and Wednesday evenings, at 7½ o'clock, beginning November 17, by Instructor Krauss.

The Corporation have held eleven meetings during the year.

At the meeting of Dec. 10, 1873, the Degree of Bachelor of Science was conferred upon 19 Graduates of the Institute; in the Department of Civil Engineering, 9; of Chemistry, 6; of Geology and Mining Engineering, 2; of Mechanical Engineering, 1; of Architecture, 1.

Profs. Watson and Rockwell have resigned during the year; Prof. Channing Whitaker was appointed in the place of Prof.

Watson, and the work of Prof. Rockwell was divided among Profs. Ordway, Hunt, and Richards.

At the same meeting was received and accepted the gift of a marble bust of the late Albion K. P. Welch, from the executors of the estate.

At the meeting of Feb. 11, 1874, it was voted to establish a Mechanical Laboratory, whenever it could be done without encroaching on the present funds of the Institute.

A valuable gift of 79 volumes of the American Journal of Science and Art (Silliman's), substantially bound, from the commencement to 1860, was made by Thomas G. Appleton, Esq.; also a cannon, the invention of the late Prof. Daniel Treadwell, by Mrs. Treadwell.

At the meeting of Feb. 20, on a proposition of the Boston University was voted that the Professors of Physics in the Institute thorized to receive a class in Physics from the Boston University, for one year, on conditions presented by the Committee on the School.

On April 8, was presented, from Mr. Cummings, a marble bust of Prof. Wm. B. Rogers, with pedestal.

At the meeting of June 16, it was voted to confer the Degree of Bachelor of Science on the following students, who had successfully passed their examinations, and fulfilled the required conditions:

Herbert Barrows	Reading	Dep't of Civil Engin'ing.
Wm. T. Blunt	E. Somerville	" "
George E. Doane	Middleboro'	" "
Joseph S. Emerson	Hawaiian Is.	" "
Elliot Holbrook	E. Abington	" "
Aechirau Hongma	Japan	" "
Chas. P. Howard	Hartford, Conn.	" "
Herbert B. Perkins	Ware	" "
Edward S. Shaw	Cambridge	" "
Arthur W. Sweetser	Cliftondale	" "
George H. Barrus	Reading	Dep't of Mech. Eng'ng.
Willis H. Myrick	Peterboro', N. H.	" "
Frank H. Pond	Woonsocket, R. I.	" "
Francis H. Silsbee	Salem	" "

Frank H. Jackson	Brighton . . .	Dep't of Mining Eng'ng,
Wm. B. Dowse	Boston	Dep't of Architecture.
Robert C. Ware	Marblehead . .	Dep't of Sci. and Liter.
Stephen H. Wilder . . .	Cincinnati, O. .	" "
Benj. E. Brewster (1872) .	Boston	Dep't of Mining Eng'ing.
Geo. W. Blodgett (1873) .	Boston	Dep't of Civ'l Engin'ing.
Sam'l M, Felton, Jr. (1873)	Thurlow, Pa. . .	" "
Frank W. Very (1873) . .	Salem	Dep't of Chemistry.

Subjects of Theses, with abstracts, will be found on p. 81.

The progress of the school in the various departments will be found in the reports of the Professors, and the President.

SAMUEL KNEELAND, *Sec.*

DEPARTMENT OF GENERAL CHEMISTRY.

President Runkle: —

DEAR SIR: — As the changes which have been made during the past year in the Courses of Instruction have involved some changes in the instruction in General Chemistry, it may not be inappropriate briefly to allude to the plan at present pursued.

The method originally adopted for teaching Elementary Chemistry was based upon the ideas, — 1st. That all the regular students of the School should receive a certain amount of instruction in General Chemistry and in Qualitative Analysis. 2d. That some knowledge of the facts and principles of the science should precede the attempt to learn Qualitative Analysis, with which branch of the subject the instruction in some institutions begins. 3d. That the proper method of learning these fundamental facts and principles is by actual work in the laboratory where the student sees and handles for himself, this laboratory work being supplemented by systematic study of the text-book, enforced by familiar lectures or oral explanations. This system has been followed since the laboratory was opened, and there is no reason to feel that any better general plan could be pursued.

The amount of time devoted to the subject by the students of those regular courses which do not involve a knowledge of Chemistry as a prime necessity has been somewhat decreased, and the allotted time so distributed that now the entire course

in Elementary Chemistry is completed during the First Year, instead of extending over two years as formerly. This change was made with the present Second Year's Class during their First Year, and they in consequence suffered from the change, but that the effect of this concentration of work will be felt to be beneficial in the case of the present First Year's Class, I have not the slightest doubt.

Methods of Instruction. — A regular student of the First Year's Class now attends each week two exercises in the Laboratory (of two hours each), one recitation, and one lecture. Frequent *written recitations* and regular monthly *written examinations* serve to inform the student of progress made and to give warning if necessary. During the first term the laboratory exercises are devoted to chemical manipulation: each student performs, under the supervision of the Professor and of his assistants, a large number of experiments intended to illustrate the laws of chemical action, and the properties of all the more important chemical elements and their principal compounds. During the second term the laboratory exercises are devoted to the practical study of Qualitative Analysis.

The text-books used both in General Chemistry and in Qualitative Analysis, were prepared expressly to meet our own wants, and for use in our own laboratory.

Lectures. — The lectures, if indeed they can be designated by this term, are familiar expositions and are intended simply to aid the student by calling attention to the more essential points of the subject under discussion, and to allow the performing of a few important experiments which are either too complicated or too dangerous to be undertaken by beginners. At present the students are almost all entirely new to the subject, and, indeed, to any subject of like character, so that the multiplication of experiments beyond those described in the text-book used tends to confusion, and the performing of striking experiments involving complicated apparatus tends to distract the mind from the real point at issue. Hence the apparatus em-

ployed is of the simplest kind, and the lack of *lecture-apparatus* is not under the circumstances felt as a misfortune.

Instruction during the Second Year.—The students who pursue such courses as involve the subsequent study of Quantitative Analysis continue, during the first term of the Second Year, their laboratory work in Qualitative Analysis, and the students in the courses of Chemistry, Metallurgy, Natural History, Physics, Science and Literature, and Philosophy study the principles of Chemical Philosophy.

Assistants. — Except during the very early years of the School's history, the assistants have always been persons who have acquired their knowledge of chemistry in our own School and are, consequently, familiar with the usages and traditions of the laboratory. At present, two assistants during the first term, and one during the second term are assigned to aid in the instruction, but all the class work, — recitations and lectures, and the inspection and correction of the examination papers is entirely performed by the Professor himself.

Appliances.—It is perhaps not necessary to allude to the disadvantages under which the department of Elementary Chemistry labors in having only one Laboratory, and that none too spacious, in which must be given the instruction, both in chemical manipulation and in Qualitative Analysis, — a matter of less discomfort, to be sure, this year than last, when the laboratory was taxed to its utmost capacity. In addition to the regular classes the laboratory has also to accommodate a "Lowell" Class, and this year we have been obliged to encroach upon the little space remaining in the lower entry by the erection of temporary cases for the storage of apparatus.

Laboratory of Research. — Another need of this department of the Institute is a laboratory for the private work of the Professor. At present our only accommodation is a small room 25 by 23 feet, one portion of which is partitioned off for a weighing-room, and another portion for a hood. This room, which is also badly ventilated, is the only place afforded for analytical and other laboratory work to the Professor of Industrial Chem-

istry and his assistant, the Professor of Mining and his assistant and the Professor of General Chemistry and his assistant.* It seems appropriate that the Chemical Laboratory of the Institute of Technology should be a place to which chemical questions arising in the various departments of the State and also in the case of private individuals should be brought for solution. In spite of our limited accommodations which prevent us from making efforts for this kind of work, except during the summer vacation, considerable of such work has been done. The receipts, which are divided between the persons doing the work, and the "library-fund" of the chemical department, have enabled us to acquire some of the more important works of reference, — a nucleus of what we hope may some time grow into a sufficiently complete *working-library*. At present we have no proper place for its reception, as its separation from the acid fumes of the laboratory is impracticable owing to lack of space.

Although this is not strictly connected with the instruction in General Chemistry, I may in this connection allude to the investigation of certain scientific and practical questions undertaken at the request of the State Board of Health. These investigations have been as follows: —

1870. In the Second Annual Report of the Board of Health appears a report by W. R. Nichols, "On the action of Cochituate water on lead pipes," (recording the results of 10 determinations); also, a report by W. R. Nichols, "On the condition of Mystic Pond and its Sources of Supply," (involving some 100 separate determinations); also a report by A. H. Pearson of the results of more than 75 determinations of "The amount of carbonic acid in the air of various schoolhouses in Boston and in the outer air in different localities, and under different circumstances." These experiments were made under the direction of Professor Storer.

* The Professor of Analytical Chemistry occupies a corner of the chemical storeroom.

1871. The Third Annual Report of the State Board of Health contains a paper by Dr. F. W. Draper of Boston, "On the evil effects of the use of arsenic in certain green colors." Several analytical determinations made by Mr. A. H. Pearson in our laboratory are there recorded.

1872. The Fourth Annual Report contains a paper on "Sewage, Sewerage, etc., prepared by Dr. George Derby and Professor Nichols. The analytical work, involving some 1100 single determinations, was performed mainly by Miss E. H. Swallow in our laboratory. Investigation was also made into the character of certain slaughter house products.

1873. The Fifth Annual report contains a paper by Professor Nichols, "On the present condition of certain rivers of Massachusetts, etc." The analytical work involved more than 1300 single determinations, nearly all made by Miss E. H. Swallow, one of our graduates.

1874. The present year, for sufficient reasons, not very much has been done; still it is hoped that an investigation now in progress, the results of which will appear in the Sixth Annual Report of the State Board of Health, may not be without interest and value, and another research more important in its practical bearings is a portion of the work laid out for next year.

The advantages to the Institute in thus being recognized in the service of the State seems to me not unimportant, and the pecuniary return more than covers all expenditure for gas, water and chemicals, so that the Institute incurs no expense directly or indirectly, in the matter.

All of which is respectfully submitted.

WM. RIPLEY NICHOLS,
Professor of General Chemistry.

REPORT OF WORK IN THE DEPARTMENT OF PHILOSOPHY.

To the President: —

By the changes consequent upon the new Course of Study, adopted last January, the work devolving upon my chair is now divided into two distinct parts: (1) that required of all regular students, as a condition of a degree in any department; and (2) that required, in addition, of regular students in the department of Philosophy,— a department created at the time of adopting the new course. The report of what I have done the present year, may conveniently treat of these two parts separately.

I. THE WORK DONE WITH ALL REGULAR STUDENTS.

This, during the first half year, before the new course went into operation, comprised (1) two lectures a week, on the Syllogism, and on the Rudiments of Inductive Logic, with the Fourth Year's Class; (2) two lectures a week, on the Doctrine of Terms and Propositions, with the Third Year's Class; and (3) one lecture a week, on the Structure and Analysis of Terms and Sentences, with the First Year's Class. For this last, the class was divided into two sections.

The work, on the part of the Fourth and First Year's Classes, was of a high order; both passed a very thorough

examination at the Semi-annual in January. I was able to use far more complete and difficult papers than those of the preceding year, and yet the results were quite as good. This examination brought my connection with the Fourth Year's Class to a close; and their performance of duty, throughout my acquaintance with them, has seemed to me so unusually commendable, that I cannot dismiss them from this report without a special acknowledgment of the industry, sympathy, intelligence, and success which have constantly marked them while under my instruction.

The work with the Third Year's Class was broken short in the midst, by the operation of the new courses. This interruption of plans laid out and worked upon before any definite knowledge of the proposed changes was in my possession, of course made the subject appear to the class in a very incomplete and unsatisfactory light, and caused the semi-annual examination in it to seem unreasonable. Nevertheless, they succeeded in passing a pape of unusual difficulty with decided credit, only three out of the forty-seven members of the class having been subjected to conditions.

With the opening of the second half year, in February, the new course went into operation. It was, however, decided to let my plans for the First Year's Class go on as laid out at the beginning of the year. I therefore continued to lecture to them once a week till the year closed.

My regular work with the Second Year's Class now commenced, and occupied three lectures a week for the remainder of the year, covering in outline the whole subject of Formal Logic, exclusive of Fallacies. The result with this class seems to indicate that the place and time allotted in the new course of study to the subject of Logic (the second half of the Second Year), can be made to answer a more useful purpose than I had thought they could. Although the *amount* of ground covered has been less than I should like to see, as the limit to be reached in that study in the Institute, the quality of the work has been good. In future, too, I believe we shall be

able to include in our work not only the positive theory of the Syllogism, but the doctrine of Fallacies as well. I hope to accomplish this by finishing so much of the theory of Propositions in the First Year's work, as will enable us to commence the instruction of the Second with the doctrine of Inferences. To make sure of this, however, I recommend that the Institute shall in future require, as a condition for entering the First Year, a thorough acquaintance with the classification and analysis of terms, and with the parts of a proposition, and a respectable skill in analyzing sentences, both simple and complex.

As to methods of instruction, I may refer to my report of last year. The only change has been, to increase somewhat the number of preliminary written examinations, held at intervals during the progress of the lectures. These have averaged, for each class, about one in three weeks throughout the present year.

II. THE WORK IN THE DEPARTMENT OF PHILOSOPHY PROPER.

In this new department, placed under my charge, there have been enrolled, the last half-year, five students: three regulars — one of the Second Year and two of the Third — and two specials. The latter took the introductory course in Psychology prescribed for the Third Year, and the course in Ethics prescribed for the Fourth Year.

The programme of work, as shown in the course of study printed in the last annual catalogue, has been quite completely carried out. The five students, without exception, have passed successful examinations, — a fact the less remarkable, when it is recollected that they are all students from preference, having chosen the department from a conviction of its adaption to their wants, and from a sincere interest in its leading subject.

The instruction has been given directly by lectures, three a week on a general introduction to Philosophy, and on Psychology, and three a week on Ethics. Much reference of the students to standard texts as companions to these lectures, has

however, been employed. For this purpose, I have used, with the Third Year men, Bowen's edition of Sir W. Hamilton's *Metaphysics*, portions of Stirling's translation of Schwegler's *History of Philosophy*, portions of Mill's *Logic* and of his *Examination of Hamilton*, parts of Ueberweg's *History of Philosophy*, and of the *Prolegomena* to Krauth's edition of Berkeley's *Principles of Human Knowledge*, and Masson's *Recent British Philosophy*. The Fourth Year Specials have read and discussed the most important parts of Calderwood's *Handbook of Moral Philosophy*, together with an outline of Kant's theories in the field of Ethics. Both classes have done a considerable amount of parallel reading on their own account.

The range and character of the work done will be clearly seen in the subjoined papers, used at the annual examination in May: —

DEPARTMENT OF PHILOSOPHY.

PSYCHOLOGY — THIRD YEAR.

May 22, 1874.

1. If we regard the subject merely from beforehand, what may we lay down as a provisional definition (or description) of Philosophy? Can you see any reason in this, why Plato should have called it a "meditation of death"?

2. If we attempt a scientific definition of it, after effectual acquaintance with its procedure and its results, what threefold distinction in regard to it must we make in order to avoid confusion, and to prevent us from supposing definitions to conflict, which are in reality quite harmonious?

3. Keeping this distinction in mind, endeavor now to define Philosophy from each of the three points of view.

4. In the light of what precedes, what would you say of Hamilton's statement that Aristotle, in calling Philosophy "the art of arts, and the science of sciences," merely intended to describe its supreme eminence? What, probably, *did* Aristotle mean?

5. In general, what two great fields does Philosophy include? Distinguish between them as accurately as possible.

6. Tabulate the schools of Philosophy, as they have thus far appeared in history, arranged upon the principle of their *Theory of Knowing*.

7. Do the same, upon the principle of their *Doctrine of Being*.

8. Endeavor to make out a division of them according to their *Method of Research*.

9. State the doctrine of the Relativity of Knowledge in its most general, least determinate form, i. e., as held in common by *all* Relativists.

And the form it assumes in the hands of Transcendentalists.

And the intense form of it peculiar to Empiricists.

Are these two schools necessarily Relativist?

10. Why may Kant's "Critical" philosophy justly be termed Transcendental Skepticism? Why is Hume's called Empirical Skepticism? Is there any essential difference in their theoretical results? In their practical?

11. How does Hume's Skepticism differ from Nihilism? How can you account for its being so repeatedly charged by able men with being essentially the same doctrine?

12. How would you distinguish a *Person* from an *Individual*; or, more exactly, *personality* from *individuality*?

13. State the doctrine of the Trinity, as involved in Pure Consciousness — i. e., in the *Idea of Personality*.

14. In what sense does this Trinity "appear" in Consciousness the Sensation, and in what sense not?

15. Where do the English, the Scottish, and the Positivist schools of Philosophy all essentially agree in placing the "Beginning" of science? Why must this render it certain beforehand that they can never establish Substantive Being? What does this show in general, in regard to the effect upon Philosophy of the Psychologic starting-point?

16. In what peculiar manner does Hamilton regard the term *Psychology*? In what way does he then divide the field which he thus denotes? In doing this, what further departure does he make from the general usage of philosophers? Is the *distinction itself* which he makes here valid? Give your reasons.

17. When Calderwood says that the Ego is given *immediately* in consciousness, what does he mean, and what criticism may be made upon his view?

18. Distinguish between "consciousness" and "self-consciousness." State Hamilton's peculiar views in this connection, and criticise them, both from his own contradictions and from the facts.

19. Why is Hamilton's philosophy of Perception called *Natural* Realism? Why *Dualistic* Realism? Where does he find the theoretic warrant for his two Substances?

20. Give Hamilton's classification and nomenclature of the "Faculties" — and the common names along with his technical ones. What *is* a "faculty"?

DEPARTMENT OF PHILOSOPHY — YEARS III, IV.

EXAMINATION IN ETHICS.

May 25, 1874.

I.

Write as complete and as accurate an account as you can, of the so-called *Intuitional Theory of Morals.*

Show what it is intended as a theory to account for; making all the necessary distinctions between processes of knowing, of feeling, and of acting.

Show how it finds the warrant for obligation, having defined Obligation.

Show, also, how it states the universal *Law of Virtue*, i. e., in what it makes Virtue essentially to consist, irrespective of the particular form.

Show the peculiar difficulties to which the theory is liable, and how its advocates attempt to overcome them.

Show the distinction between Judgments of Right and Judgments of Duty. Decide whether Calderwood, under this distinction, really includes all the vital facts of moral consciousness. If you think he omits any, show what, and why you think so.

Discuss Conscience. Point out the distinction between Rights and Right.

Make as good a list as you can of what Intuitionalists generally consider the *à priori* First Principles of Right.

II.

Present a similar treatment of the so-called *Development Theory of Morals*, going into details as far as you have time. Take especial

notice of its doctrine concerning the origin of knowledge in general, the origin of conscience in particular, and of its most general Principle of Rectitude.

III.

Make a list of the leading philosophers who have advocated either view.

It deserves mention, that, although answers to but half of the foregoing questions were *required* of the students, and the students were allowed to select this portion for themselves, they voluntarily offered answers to all, and that a great majority of these answers were satisfactory.

I think these results entirely justify the course of the Government in creating this new department. To ensure its complete success, I believe it will only be necessary to carry out, as far as possible, with respect to it, the principle of equipment with the requisite implements and laboratories (if I may be allowed the expression), which characterizes the administration of instruction in the other departments of the Institute. The proper "laboratory" of a department of Philosophy, is, of course, a sufficient collection of the works of those thinkers who have really contributed to the historical development of Philosophy, together with such illustrative commentaries and charts presenting systematic views as wholes, as will serve at once to instruct the student and to stimulate him to independent investigation. In short, the need is a good special *library*, properly arranged for rapid consultation, and yet in some place suited also for the most patient study, with appliances enabling the student to make his own abstracts and charts of systems, where such are needed.

The beginning of such a library has been put in our possession. The department has now a room sufficient for its immediate wants, and the nucleus of a special collection in philosophy, from a small appropriation assigned us during the year, is already obtained. This, together with the works in my own collection, will answer all purposes, provided it can gradually

be increased as the department goes on. A very small annual appropriation for this object — so little, even, as fifty dollars a year — will serve to meet the probable wants of the department as it develops, and, in the course of time, to secure a positively *complete* collection of such works as are of any real significance in this field of knowledge.

The progress of my instruction in this department has already convinced me that important alterations must be made in its course of study as printed in the last catalogue. More time must be assigned to its special subjects in the Third and Fourth Years, and those subjects must be brought in a prominent and special form into the Second Year. To make room for these changes, certain of the miscellaneous studies, now pursued by students of this department in common with those of other departments, must be dropped. The details of these alterations will be presented to the consideration of the Faculty at an early day in the ensuing year.

Respectfully submitted,

GEO. H. HOWISON.

Boston, June, 1874.

REPORT UPON THE LOWELL SCHOOL OF PRACTICAL DESIGN.

Mr. President: —

At the close of the second year I have the honor to submit the following Report of the progress attained in this Department: —

The second annual session of this school commenced with twenty-six pupils, — fifteen old and eleven new ones. The old pupils started at the beginning of the year, upon original compositions; and gradually so improved, that the results proved highly satisfactory to me, and commendable to themselves.

The new pupils after working from copies until January, and having gained skill in execution, were put upon such variations of work as naturally lead them to produce original compositions. This change proved also, in the highest degree, beneficial, and all of them exhibited great originality in their subsequent efforts at composing.

During the month of May last, I sent from time to time all the original designs, from both classes, to different manufacturers, for inspection; and every manufacturer who saw our samples, purchased some of them. Thus 23 patterns were disposed of to the amount of $200 — each pupil receiving the money for his or her specimens.

Two young designers have been furnished, from the advanced class, to the Pacific Mills, where they are now perma-

nently engaged, giving great satisfaction. We have had two public Exhibitions, one at Horticultural Hall, Boston, and one at Huntington Hall, Lowell — which have proved highly attractive and interesting to the public.

The school also contributed to the art department at the late exhibition of the Mechanics Charitable Association, held in Boston, and was awarded a prize of a gold medal.

I am happy to add that the pupils in this school evince great application and perseverance in their studies, as well as good will; and I can very confidently affirm that their patterns exhibit generally a goodly share of taste and originality in design.

It is with great pleasure that I am able now to state that, in my judgment, we shall be able hereafter to furnish from this school well qualified American designers, in all branches of this important art.

The generous contribution made last year by Mr. James L. Little, has not yet been exhausted. The "Claude Fréres patterns," furnished to the School, by Mr. Lowell, have proved an invaluable aid in the work of the past year.

I am, very respectfully,

Your Ob't Serv't.

CHA'S. KASTNER.

THE DEPARTMENT OF ARCHITECTURE.

President Runkle:—

DEAR SIR: — The instruction given during the last year in the Department of Architecture did not materially differ in character from that of the previous year. Three regular students and about twenty special students have been in attendance, about the same number as in previous years. But the quality of the classes visibly improves from year to year, partly because it has been found that young men without either character or intelligence are no better suited for these studies than for others, so that we are no longer troubled by their presence, partly because the department has come to be favorably known in the more distant parts of the country, and, other things being equal, students who come a long distance are in general the best workers. It has accordingly happened that the results of the year's work have been more satisfactory than in any previous year, as good work has been done and more of the work has been good.

At the beginning of the year one of the two students who passed the final examinations the previous year presented his thesis and received his degree. The subject chosen was a building for water-works in a public park. The drawings showed the arrangement and aspect of the building itself, with the machinery for pumping and controlling the water. The text accompanying them contained calculations of the dimen-

sions of the principal parts of the structure and of the flow and supply of the water.

During the year the rule was adopted that the graduating thesis should be presented before the close of the school year. A second thesis and the accompanying drawings was accordingly presented in May, by the student who passed his final examinations at that time. The subject chosen was a Railway Station, situated on a bridge over the track. The drawings showed the structure in plan, elevation and section, with details of the wood, iron and stone work. The thesis itself discussed the thrust and equilibrium of the arches, the strength of the retaining walls, the resistance of the tower to wind, etc., etc.

The Third Year's class, to which most of the special students were attached, were occupied during the year with the following problems: — 1, an arch; 2, a *Porte-cochère*; 3, a Portico; 4, a Peristyle; 5, a Staircase; 6, a Billiard Room; 7, a Pompeian House; 8, the use of Four columns; 9, a Monumental Bridge; 10, a School of Architecture; 11, a Dwelling House. At the same time the Fourth Year's class made designs for 1, a Temple Tomb; 2, an Iron Pavilion; 3, a *Café Chantant*; 4, a School House; 5, a Railway Station. This class also made sketches of most of the problems given out to the other class. They also made careful drawings of King's Chapel, to which the Wardens kindly allowed them access at convenient hours. Two of the designs for the Railway Station were given in the September number of the Architectural Sketch Book, a professional journal published by Messrs. Osgood & Co.

The course of History this year covered the Greek and Roman Period, as usual, in the first half of the year, and in the last half the period of the Renaissance. The usual lectures in construction were continued through the year. The collections have not been materially increased.

I am, very truly,

Your Ob't Serv't,

WILLIAM R. WARE.

REPORT OF THE DEPARTMENT OF MILITARY INSTRUCTION.

President J. D. Runkle: —

Sir: — Since rendering my last report, the discipline and efficiency of the corps of students receiving military instruction has been much improved, and comparatively little discontent is now apparent. I have endeavored to make the instruction as little burdensome as was consistent with making it efficient. The instruction was given under many disadvantages, not the least of which was the want of a proper drill-room. Whilst the disciplinary rules which were adopted were neither harsh nor severe in themselves, they were felt as irksome by some of the students who had been accustomed to the comparatively loose discipline, or rather, absence of discipline, which prevailed previous to my reporting for duty. I have observed that the few cases which were at all troublesome were invariably those of students who were troublesome in other departments of the Institute. The inference then is fair, that the difficulties of making the military instruction at the Institute both respectable and efficient, are not inherent in its incompatibility with the strictly civil character and proper work of the school, but rest more particularly with the individual character of its students. In order to make military instruction effective, military discipline must be enforced during the hours assigned for that purpose. This discipline is necessarily more minute and less yield-

ing than the ordinary discipline of a civil school, such as the Institute of Technology. But the inflexible exercise of it, at stated times, must have a tendency to make the students more amenable to the general discipline of the school, and of rendering impossible the stay of those unruly characters whose presence is injurious than otherwise.

In addition to the instruction in infantry drill, some instruction was given in artillery drill and signalling. Voluntary practice in day and night signalling was given at distances between stations ranging from one to six miles, and many of the students became skillful therein. The success of this instruction is due chiefly to the able efforts of Mr. Henry N. Mudge, who was Signal and Ordnance Officer during the greater portion of the year. Aside from its utility as a military exercise, the instruction in signalling may be useful to the students whenever they may be called upon to perform surveying, or other similar out-of-door work. It enables them to communicate at distances far beyond the reach of the human voice, but within the range of vision. It requires no special apparatus or preparation for either day or night communication.

Lectures were given on the following subjects, viz:

1st. "Discipline"—manner of establishing and enforcing it.

2d. "Feeding troops"—ingredients, proportions and manner of preparing food in camp and on the march.

3d. "Military Hygiene"—sanitary measures necessary in camp and on the march.

4th. "Military Courts"—composition of, principles governing their actions, and the forms of procedure.

It is my intention to continue with the second year class, during the school year of 1874–75, the lectures upon the 3d of the above mentioned subjects. My aim in giving these lectures is to give the instruction which is essential to the proper care and preservation of the health and efficiency of troops when exposed to the abnormal conditions of the camp and the march. This instruction may be useful to the students when, as engineers, they are called upon to assume charge of large bodies

of workmen in the construction of railroads, or other similar work. A knowledge of the proper manner of feeding and taking care of these laborers can not but increase the efficiency of their services, and the amount of work accomplished in a given time.

The lectures upon Military Courts were given with a view of enabling the students to enforce their own discipline by courts composed of the officers of the corps.

The officers of the corps labored under great disadvantages in the instruction of their respective commands. There was such an absolute certainty of a change in the then existing system of tactics, that they felt and received but little encouragement in studying up the details which are so essential in acquiring proficiency of drill. They are deserving of much credit for the thoroughness with which they performed all duties assigned them. I beg leave to mention their names in this report, viz.:

STAFF OFFICERS RANKING AS FIRST LIEUTENANTS.

Adjutant,	B. Leighton Beal.
Quartermaster,	F. M. Learned.
Signal and Ordnance Officer,	H. N. Mudge, resigned, succeeded by C. H. Goodrich.

	Captains.	*1st Lieuts.*	*2d Lieuts.*
Co. A.	T. Aspinwall, Jr.	G. C. Avery.	C. L. Dennett.
Co. B.	T. E. Schwarz.	W. D. Townsend.	J. B. Henck, Jr.
Co. C.	W. R. Munroe.	W. R. Cabot.	J. M. Wilson.
Co. D.	C. F. Main.	E. L. Caldwell.	S. W. Holman.

At the close of the school year, about fifty students desired to go into a voluntary encampment for a week. It was not at that time considered expedient to permit them to do so. Such encampment coming immediately after the severe tasks imposed by the annual examinations would serve as a most healthful relaxation, enabling me, at the same time, to impart some useful instruction. The experience would be such as to be useful to them as engineers, when required by their work to live in tents. Opportunities would be afforded for base ball, foot ball,

and other healthful out-of-door sports. Whilst such an encampment would serve as a recreation to the students, I feel confident that it will go far, from the pleasant associations which it will undoubtedly engender, in making more acceptable the military instruction, absolutely required as it is. I trust therefore that permission will be granted for this purpose.

So much of the school year of 1874–75 has elapsed at the time of writing this report, that I take the opportunity to briefly mention some of the changes which have been made during that time.

As a mistaken impression regarding the relative status of the military element seemed to have been gaining ground in the minds of some of the friends of the Institute, every effort, consistent with its efficiency, has been made to render it as little conspicuous in appearance as it is in fact. With this in view, black gutta-percha buttons have been substituted for the bright metallic buttons heretofore worn. The uniform, thus changed, is inconspicuous.

In compliance with the recommendation embodied in the report of the Committee of the Corporation "On the Military Instruction given at the Institute of Technology," the amount of writing necessary in the transaction of official business has been reduced as far as practicable. The amount of "red-tape," so called, which was demanded of the majority of students, has been much exaggerated. It was, in fact, a demand of less than *five* minutes labor in writing explanation for one or more absences from *required* exercises, and but little more than *one* minute's labor in writing an explanation of tardiness.

The manner of appointing the officers is somewhat different than that of last year. Only *acting* appointments have been made, subject to approval and confirmation by the Faculty. The *full* appointments will be made after the semi-annual examination, at which time they will doubtless have shown their degree of fitness for different offices. The details of instruction and discipline have been left, in a greater measure than last year, in the hands and control of the officers. They have

performed their duties with a sound judgment and discretion. The burden of the responsibility in disciplining and instructing the corps has rested upon the acting Captains commanding companies. I would ask no better fortune, should I be called upon to organize a regiment for actual service, than to have these young gentlemen as my assistants. The acting Adjutant, Quartermaster and Signal and Ordnance Officer have efficiently performed essentially the same duties which they would be called upon to perform in actual service. The roster of acting commissioned officers is as follows, viz.:

STAFF OFFICERS RANKING AS FIRST LIEUTENANTS.

Adjutant,	J. F. Swain.
Quartermaster,	E. H. Gowing.
Signal and Ordnance Officer,	C. Cushing, Jr.

	Captains.	*1st Lieuts.*	*2d Lieuts.*
Co. A.	A. K. Plimpton.	W. E. Chamberlin.	W. B. Bradford.
Co. B.	C. H. Norton.	C. H. Fisher.	W. S. Frost.
Co. C.	F. E. Peabody.	H. E. Monroe.	W. M. Peters.
Co. D.	W. Jenney.	I. M. Story.	F. P. Spalding.

The report of the Committee (previously mentioned) leaves nothing for me to say regarding the beneficial effects of military instruction, from physical and mental points of view, nor of its necessity from patriotic motives and an honest intention to comply with the spirit, as well as the letter, of the terms of an obligation assumed. I feel confident that the graduates of the Institute will serve with credit in the ranks of the citizen soldiery, should they be called upon to defend their homes and liberties.

Respectfully submitted,
E. L. ZALINSKI,
1st Lieut. 5th U. S. Art'y.

REPORT ON MILITARY INSTRUCTION.

The Committee appointed by the Corporation of the Institute "to take into consideration the whole subject of the military instruction to be given in the Institute," beg leave to present the following

REPORT.

Chapter 186 of the Acts and Resolves of the Legislature of Massachusetts for 1863, contains the following provision, namely: "Said Institute of Technology, in addition to the objects set forth in its Act of Incorporation, shall provide for instruction in military tactics." This condition forms part of the Act which appropriates to the Institute one-third part of the annual interest or income received from the fund created by Act of Congress approved July 2d, 1862, granting public lands of the United States for certain purposes of education.

So long, therefore, as the Institute shall continue to receive this endowment, "instruction in military tactics" seems to form a necessary part of its curriculum.

Accepting this condition as imperative, the only questions open for consideration respecting military instruction must relate to the amount, the kind, and the modes of imparting it. It is hardly possible in a report of this kind to discuss fully the value, either absolute or relative, of instruction in military tactics; a few considerations may be presented. And first of all, it is well to remember that at the time when the Legislature

selected the Institute of Technology as one of the institutions which might receive the national bounty for educational purposes, the country had but recently entered upon the great civil war, when its untrained army, composed largely of volunteers, almost wholly destitute of military knowledge and practice, were encountering the fatigues of the march and the camp, and the perils of the battle-field. Surely any provision which is the offspring of such a crisis as liberty or slavery, of life or death, must be regarded with the deepest interest. In any country, however peaceful, yet subject to the exigencies of war, and relying less upon the strength of a standing army than upon the patriotic response of its citizens to any necessary call to arms, the value of some practical knowledge of military tactics by its people, and especially by its educated classes, is too obvious to need argument. A striking illustration is given in a communication written at the time of which we are speaking, concerning the students at the United States Naval Academy, at Annapolis.

"When Washington was defenceless, Baltimore in riot, and all Maryland in a state of revolt, communication being cut off at Annapolis, there was great fear of an attack upon that important strategic point. The pupils were prepared for any exigency, and slept with their loaded rifles over their cots. At an alarm of a night attack, there was no hesitation among those gallant little fellows. They were up directly; fell in their ranks and off at *double quick* for the point of danger in an almost incredible short space of time. The elder boys dragged their howitzer with them. Had an attack taken place, those pupils would have given a good account of themselves, and have stood their ground with courage and steadiness. The secret of this is *discipline*, for which they are indebted to the assiduity of their brave and experienced Superintendent, Captain Blake, of the Navy."

Had even a tithe of this military discipline been received by the men who composed the loyal army at the beginning of the war, how vast might have been the saving of life, of suffering and of property! It was doubtless the inevitable recognition

of this fact which induced the Legislature to impose the condition, that those who participated in the benefits of the national bounty for educational purposes in this Institute, should become qualified to return a special service in the field, should such be required for the national honor and welfare. The national academies of military and naval science and practice will continue to afford the means of educating a limited number of officers for the regular Army and Navy on a peace basis; but it is neither practicable nor desirable so to enlarge these institutions as to embrace corps of students sufficient in number to lead the volunteer forces in case of war. It is not desirable to cultivate a warlike spirit among our people, nor to withdraw from civil pursuits, to be maintained at the public cost, a needless force of military men. The safest and most feasible alternative seems to be found in making instruction in military tactics a part of the curriculum of our higher schools. As the country shall increase in extent and population, and these institutions in wealth and diversity, it may be useful and desirable, should the domestic and foreign relations of the country require an increase of military men of high culture, to establish in some of them departments of military science as parts of a university system. No such department has been established in the Institute of Technology, and none is now recommended. Since, however, instruction in military tactics is promised by accepting the legislative bounty, it is doubtless the purpose of the Corporation that this obligation shall be fulfilled in the true spirit and intent of the statute, and in such manner and with such results as shall correspond with the general vigor and thoroughness of study and discipline in all other departments of the Institution. In the opinion of your committee, the value of military instruction and discipline is by no means to be estimated alone by their possible relations to a state of war, when the citizen is transformed into the soldier. Such instruction has great and peculiar value as an educational and disciplinary agency, and as a sanitary exercise of the highest type. It cultivates habits of neatness, order, precision, quickness of

thought and action, and that absolute obedience which those must first learn who are afterwards fit to command. It inspires a manly and chivalric spirit, gives ease of carriage and movement, develops muscular energy and endurance, and stimulates the intellectual powers by kindling all the vital forces into healthy activity. If, therefore, education be interpreted as a process of developing the intellectual faculties, as well as a mode of receiving and classifying knowledge, it is believed that military tactics compare most favorably as a branch of study, with certain branches of mathematics, and with many other studies which especially engender habits of concentration and persistent application. Military practice is certainly superior to either in the particular that it blends recreation with acquisition. If we mistake not, the courses of study in the National Military Academies are as difficult of accomplishment as are those in the average of American colleges; and yet they are completed in as many months as the college courses, notwithstanding students in the former are subjected to frequent and protracted military exercises daily. And testimony is abundant to prove that the time employed in the military drill is more than accounted for in the increased mental activity and energy which it produces. In a letter to the chairman of this committee, Rear Admiral Worden, Superintendent of the United States Naval Academy, says:

"The average time assigned to the drill of each student during the academic year (eight months) is seven hours per week. This includes the time occupied by all seamanship, Great Guns, Field Artillery, Boat Howitzers, Infantry, Fencing and Boxing Exercises and Dress Parades. Besides these exercises, those members of the Fourth Class who enter in June, are practised in gymnastics during the summer months, three hours every week, and in swimming every morning. The Third Class has instruction in gymnastics about three hours per month; and all the classes are invited and encouraged to use the Gymnasium for exercise during recreation hours. The average time assigned to drill in Infantry tactics does not exceed two hours per week throughout the academic year. . . . . As to the

amount of drill which can be profitably employed in such a school as the Massachusetts Institute of Technology, for purposes of exercise, discipline, etc., I am of opinion that one hour per day could be so appropriated with great advantage to the physical culture and mental development of the students. . . . . I have always been strongly impressed with the necessity of bodily culture as the true complement of mental development; and I know of no readier and more congenial method of obtaining a good result than the practice of military exercises in the full meaning of that term. For in that sense what is called military training — a kind of training which is but a small part of a military education, and which ought to be *common* and not peculiar to soldiers and sailors — is to be valued not only in a muscular point of view, but as generating habits of just subordination, of manly self-control and of neatness and good order in person and personal property."

Admiral Worden also refers in his valuable letter to an elaborate article on "Physical and Military Exercise in Public Schools — a National necessity," contributed by General Edward L. Molineux, of New York, to Barnard's "Military Systems of Education," first published in 1862, and revised in 1872. In this article we find the following suggestions:

"The influence of health upon the faculties of the mind is acknowledged by all, and yet how few in this country devote attention to those important exercises which are necessary to the preservation of health, and without which intellectual power cannot be applied to its highest use. The talents, the experience of our best educators of youth are taxed to devise exercises to develop the *mental* faculties, forgetting that too close application to study is detrimental to the growth of the body. . . . . What then is the most simple, feasible and useful plan to adopt for physical exercise in our colleges, normal and public schools? We unhesitatingly reply that the only successful, orderly and systematic method is to engraft them upon the course of studies during school hours, and to carry it out under strict military discipline; the exercises being such as are best suited to the ages, strength and capabilities of the pupils, namely: calisthenics and walking for the girls and younger children, and military exercises for the elder boys."

High English authority is cited in support not only of the practice of infantry tactics in schools, but even of cavalry drill for the middle and higher grades. The Vice Chancellor of Oxford testifies that the institution of the systematized exercise of the volunteer drill in that College has been attended by an improvement of the mental labors, and of the whole of the order and discipline, as well as of the health of the University. The Honorable Joseph White, the present experienced Secretary of the Massachusetts Board of Education, and also a member, on the part of the Commonwealth, of the Corporation of this Institute, says:

"Let the drill be regular and compulsory, taking the place of the very irregular and insufficient physical exercises now taken, and our colleges would be vastly improved in their educational power, and the Commonwealth would, in a short time, have a numerous body of educated men well skilled in military science and art, who will become teachers in our lower grades of schools, and in our military companies and associations, and be competent, when the alarm is sounded, to lead our citizen soldiers to the field."

The adoption of the military drill in many private academies and high schools, which depend upon public approbation for their support, indicates the increased interest in the importance of this branch of education, and may be regarded somewhat as the verdict of experience respecting its value. The amount of instruction in military tactics to be given in the Institute, may be safely assumed to be at least so much as to answer all purposes of physical exercise, with the addition of so much as shall constitute a suitable return to the State and the country for the military bounty which the Institution receives. In their investigation of this point the committee personally examined the course of study and practice already adopted by the Institute, and also witnessed the drill exercise, and held consultation and discussion with the Faculty upon the general subject now under consideration. Much diversity of opinion prevailed among the members of the Faculty, qualified somewhat, as it appeared to

the committee, by the more or less strictly scientific nature of the departments which they represented respectively. At the request of the committee, the Faculty at a later day transmitted a letter embodying their opinion of the amount of instruction in military tactics which should be given in the Institute, together with their views upon the relation which this instruction should bear to other departments of study, and some remarks upon an alleged exaggerated and mistaken public opinion respecting it. The views expressed therein as to the time which may be allotted to military instruction correspond with those of the committee, and accord also with the present regulations. It seems to be generally conceded that two hours per week is as little time as can be given with any profit to this course, and the committee do not recommend more; although, as has been already shown, this time falls far short of what many experienced educators would assign to it, and possibly short of what experience may prove to be practicable and beneficial.

If, as we believe, the time allotted to the drill be more than compensated for in the increased physical and mental power of the students, it cannot with propriety be counted as so much consumed, which, without the drill, could be appropriated to other branches of study; neither do we concur in the suggestion that this should be regarded as an extraneous, and possibly injurious, element in our system. The committee venture with much diffidence and with entire respect to express any opinion at variance with those which have received the concurrence of any considerable number of the members of the Faculty of the Institute; and yet their investigation and their report would be of little value if they suppressed their own convictions in simple obedience to even high authority. The committee are of opinion that, whatever be the time allowed to this branch of instruction, and whatever the limitations affixed, its importance within that appropriated sphere should be as completely recognized, and its discipline as rigidly enforced, and its authority as

fully asserted and admitted, as are those of any other department.

"Instruction in military tactics" should not be regarded as an excrescent and superfluous innovation, but as an established and important element in the course of study and discipline; fulfilling thus the reasonable expectation created by the list of "Officers of Instruction," presented in our Catalogue, where there is embraced a "Professor of Military Science and Tactics." Any attempt to unduly compromise it, or subordinate it, would be to paralyze its usefulness and success, and bring it into disrepute with the students and the public. There should be no attempt to hide it from view, nor to apologize for its existence. It is due to the public and to the Commonwealth, that it shall be widely known and fully understood that instruction in military tactics forms part of the curriculum of the Institute; and that compliance with regulations concerning it, and proficiency attained in it, will be required and accounted in the meritorious standing of students in those classes in whose course of study it is found. If, then, there be students who do not wish to receive this instruction to the extent now established in the Institute, they will not be deceived by coming where by law and good judgment it is required; and no prejudicial errors will vex the public mind in consequence of any doubtful or hesitating policy upon a subject which is held in favor by many of the best educators in the world, and which seems to be gaining strength by every day's experience.

Complaints will doubtless be made by the indolent and unaspiring against all strict and positive discipline, without which excellence is seldom attained. And if the standard be lowered to meet the demand of those who would perhaps be most injured by concession, there will still be a class below who will renew the complaint; while the ambitious and hopeful student will delight in the discipline which imparts health to his body and vigor to his mind, at the same time that it measurably prepares him to discharge the highest obligations of patriotism in the hour of his country's peril. The last fear that need be

entertained is that the Institute shall excel in this attractive and important branch of instruction to a degree commensurate with its success in all other branches embraced in its Catalogue.

The committee do not recommend any other kind of military instruction than the Infantry drill already established, and what is necessarily connected with it. The Artillery and Cavalry practice, however desirable in an institution thoroughly military, and necessary to the professional soldier, are not compatible with the appointments of this Institution, nor consistent with its purposes and objects. Even within the course of instruction and practice in the Infantry drill, as now conducted, it is quite possible that the requirements in respect to certain clerical details, such as daily reports, orders, requisitions, etc., may be needlessly onerous, and that they consume time which might be more profitably employed by the officers to whom such duties are assigned. The committee recommend such modification in this particular as shall remove all ground of reasonable objection. We are of opinion that such modification may be profitable.

Two collateral topics have engaged our attention, namely: a uniform for the students and a hall for drill, which may also serve the purpose of a Gymnasium. A uniform of some kind appeared to have been agreed upon before the committee was appointed; and thus the necessity, or at least its expediency, was conceded. A sample coat of gray cloth with elaborate trimming of black braid and gilt buttons was exhibited as a style of uniform which could be obtained at moderate and satisfactory cost. This seemed to the committee too conspicuous for the purpose, and not in good taste otherwise. After some investigation and inquiry, a uniform was designed of plain blue cloth, of the Middlesex Mills, with very little trimming, and of so simple decoration generally as to be distinctive without being offensively conspicuous. It consists of a frock coat, vest and pantaloons and cap all of the same color and material. The buttons are the badge of the Institute, provided by it, as is customary with other institutions. This uniform is furnished to

the students at very small advance upon its cost to the manufacturer, and at less price than the original sample here described; and it has been generally approved for its neatness and suitableness to its purpose. The matter of a drill hall is one of much greater importance and difficulty to decide. It is manifestly very desirable that all the studies and exercises of the students shall be conducted at the Institute; and especially is this necessary for this study, if by unanimous assent of the Corporation and Faculty two hours per week, the present allotment, be all that can be allowed, and yet the least that can be used to any profit for military instruction. Any abridgment of this time in travelling to and from some remote hall must be proportionably detrimental. Indeed the great want of a drill hall at the Institute is conceded; and the only, or the chief, obstacle to its erection is the lack of the necessary funds.

No better plan than that suggested by Prof. Zalinski, of a temporary building, has occurred to this committee, and while it is not what we desire, not what can be accepted as permanent and sufficient, yet the need of some place for the purposes mentioned is so urgent and immediate, that we recommend the adoption of this one as the best that is available, and the least likely to interfere with other interests and purposes for which funds must be immediately provided.

All of which is respectfully submitted,

ALEX. H. RICE,
JOHN CUMMINGS,
EDW. ATKINSON.

Boston, June 16th, 1874.

EXPEDITION OF MINING STUDENTS TO LAKE SUPERIOR.

The professional courses of the Institute of Technology, as a rule, give a student a fair insight into his profession without going far from the city of Boston.

For the mechanical engineers there are shops, works, and factories, in the vicinity of Boston, that can be visited to give life and reality to the instruction by the Professor. For the civil engineering course there are bridges, railroads, depots, and water works, etc. The architects have buildings always at hand. The analytical chemist can learn the use of his tools in the laboratory. There seems, however, a peculiar need that the mining engineers and metallurgists should make expeditions to a great distance from the school as there are no neighbouring mining regions; if there were, there would also be other dissimilar regions at a distance. The effort to make a mining engineer without showing him a mine would be as fruitless in its result as the effort to make a sailor without allowing him to go to sea.

For these reasons it is all important that visits should be made by the students of this course to the various mining regions of the country.

Although the ores of iron, copper, lead, and silver, and the seams of different kinds of coal are all of them mined by different methods, undergo a different subsequent treatment, and occur in dissimilar deposits, still a person while visiting one mining region gains much that will be valuable to him in studying

other districts. It would be impossible in the limited time that can be devoted to expeditions, to visit a great variety of regions. It is stated in the catalogue that each mining student shall have at least one opportunity to visit one mining district during his course at the school.

The following instruments have recently been added to the equipment of the mining department especially for use on these expeditions: — a light mining transit and the German markscheide instrument with its grad-bogen.

It is deemed advisable that the second, third and fourth year's classes shall all be liable to receive the invitation to go upon expeditions. The second year will start to be sure entirely ignorant of the subject, but the expedition will add reality and interest to the subject when studied in the following year. The third year will make the excursion almost contemporaneously with their course of lectures. The fourth year, although they make the expedition a year later, yet it serves to brush up the subject in a practical way, and gives them opportunity to look about for places. There can be no fixed rule as to which classes should go on the expedition in any given calendar year, as circumstances come in to modify the case in regard to expense, time taken, and the number wishing to go.

An expedition during the summer of 1874 was made to the mining regions of Lake Superior. The party numbered fifteen, and contained members of the three professional years besides the two Professors in charge of the party.

While passing over the New York Central Railroad the party spent a day in studying the very extensive and carefully systematized salt works of Syracuse. The courteous attention of Dr. Englehardt added much to the mental enjoyment of the day, as did the thoughtful provision of Mr. J. W. Barker and of Mr. M. D. Burnett, to the physical comfort of the party. A day of recreation was spent at Niagara. The party were very kindly received by Mr. Grout of the Lake Superior Copper Smelting Company's works at Detroit. After two and a half days of pleasant sailing upon the lakes the steamer came to its

destination at Houghton, a town situated in the heart of the copper region. While at Houghton visits were made to the Pewabic mill under the superintendence of Mr. Uren. The low pressure engine is run on the exhaust steam from the Ball stamp; the pressure used is but one pound per square inch, the atmosphere doing the work.

At the Lake Superior Copper Smelting Company's works the students were in clover. Mr. James R. Cooper spared no pains to make the morning pleasant and instructive. The works are an example of neatness and order. Not a pound of copper is allowed to go to loss without being challenged by the most available methods to prevent it. Mr. M. B. Patch (graduate of Mass. Inst. Tech.) added much to the profit of the visit by explaining matters.

At the Quincy mill the large battery of heavy cam shaft stamps was a great object of interest, as they are probably the heaviest stamps of this pattern in the country. It was to Mr. L. E. Emerson and to Captain John Cliff that the party owed a very pleasant morning within the Quincy mine. The party went down the man engine calling "change" at every step. The prospecting within this mine is far ahead of the stoping. The mine excellently illustrates the value of a cross cut from a barren part of the vein to prospect its adjacent productive spot.

The Atlantic mill was visited by a few of the party. It is a very complete mill; the ore worked in it is difficult of treatment. Mr. Wm. Harris, in company with Mr. S. W. Hill, spent a morning with the party at the Houghton mill, and at the purported new vein staked out by the mysterious "Dowsing rod." The Isle Royale mill contains a very remarkable machine, consisting of four enormous edgestone wheels made of cast iron, seventy tons weight in all, or eighteen tons on each wheel. The Osceola mine was visited, but on account of the breaking of a telegraph wire Mr. F. G. White was not informed of the party's visit. Mr. Jenney, however, explained the plans. The shaft houses are arranged for a large business. On account of the fineness of the copper

grains, rolls are to be used for crushing. At the Calumet mine Mr. Wright kindly gave the party the freedom of the mine and mill. Under the charge of Mr. G. G. Richards they made a trip to the mill, which is the largest at the lake, and has a very systematic tailing mill to check the work of the other. The clerk, Mr. John Camm, gave the party over into the hands of Captain Wm. Daniell, who took every pains to make the visit below ground interesting and instructive.

At the Phœnix mine Mr. M. A. Delano courteously gave the freedom of the mill and mine. He personally showed the mill, pointing out alike its strong and its weak points. Captain Wm. E. Parnell took the party down the mine, showed the difficult survey to locate the present incline shaft, and pointed out the false system formerly pursued of working the *ash bed* for itself; also the present advantageous system of working *mass copper* mainly, and *ash bed* incidentally. He showed quantities of mass copper in sight and explained how his prospecting work was gaining on his stoping. The Copper Falls was visited. Mr. Emerson entertained the party with a nice lunch and gave them free leave to examine and criticize everything. Mr. E. R. Parks, engineer, and the mining captain accompanied the party down the mine. The extensive *ash bed* workings were noted, and the slip in the ash bed visited. The masses are not quite so large as in the Phœnix, but there seemed many of them. The circular slime buddles in the mill attracted special attention.

The party next took a week of recreation on Isle Royale, which might have been well named the Island of Mirage, on account of its numerous atmospheric phenomena of looming and deception. The party were the guests of the Hon. S. W. Hill's camp on Fish Island which lies on the north shore of Isle Royale. In Mr. Hill's boats they made vigorous raids on the fish, and their zeal did not abate at his table. The workings of the prehistoric race of men around McCargoe's cove, which were shown by Mr. Davis, are very numerous and very interesting. The rock hammers brought seventeen miles, from the north shore of Lake Superior, in canoes are found by tons. The

country is rich in copper, and parties of prospectors under Messrs. Hill & Davis are now examining veins, intending to start works should they prove rich enough. Recently very encouraging indications have been met with.

At the Island mine Capt. George Hardie hospitably entertained the party. This mine is still in its infancy. The rock resembles the Calumet and Hecla, but the rule of the mine, that is where and when the copper will probably thicken, has not yet been ascertained.

At Silver Islet the party was given the freedom of the island by Capt. Wm. B. True, who took great pains in explaining matters. Captain Trethewey accompanied them, and Mr. James C. Hill, the clerk of the company, attended to their bodily wants.

The Lake Superior Copper region has afforded an excellent opportunity for the students of the Institute of Technology to study the very systematic process of ore dressing, which has grown up in the country by the efforts of Lake Superior men, and though its machines are like in principle to those used elsewhere, the plan is entirely peculiar to Lake Superior.

On returning, the party visited some of the iron mines in the Marquette region; — the Superior mine, the Cleaveland mine, and the Angeline mine; also the Negaunee and Deer Lake furnaces. On the way home they also passed a very interesting three hours at the Chester Emery mine. The expedition left Boston June 17, and returned July 25, time taken thirty-eight days; the average necessary expense per student being $110.00, or $2.89 per day. The B. & A. R. R. and the G. W. R. R. of Canada gave half fare. The steamers reduced their fare from $32.00 to $26.00 for the round trip ticket. The hotels also made deductions. One hotel charged 64 per cent. of its regular rate, another charged 80 per cent. The week at Isle Royale cost the students nothing; the party while there being the guests of Mr. Hill's camp.

Respectfully submitted,

J. M. ORDWAY.
R. H. RICHARDS.

STUDIES IN THE MINING AND METALLURGICAL LABORATORIES.

The experiments in the mining and metallurgical laboratory during the winter of 1873–4 were mainly tentative. Each machine and each furnace needs to be proved with every variety of ore that it is likely to be called upon to work, before the laboratory can be said to be an automatic department of the school.

During the past year several studies have been made. Mr. B. E. Brewster made some experiments upon silver lead ore from the Winamuck Mine, Bingham Cañon, Utah. His report has been condensed as follows:

These experiments were tried with a view to test the capabilities of the furnaces and to furnish certain data for future experiment. The Winamuck ore at the Institute is of two sorts. One a third class carbonate from the upper workings of the mine, and the other a sample of galena from lower down in the mine. The carbonate is in the form of powder, in which no minerals are distinguishable except a few small lumps of undecomposed galena, and a large amount of quartz in small grains. A quantitative analysis of a sample of the whole gives the following composition: —

Silicious Gangue,	34.01	per cent.
Lead,	33.78	"
Silver,	.21	"
Copper,	.33	"
Ferric Oxide,	12.07	"
Alumina,	1.50	"
Zinc,	1.21	"
Sulphur,	2.72	"
Carbonic acid,	6.60	"
Water,	7.10	"
Undetermined, arsenic, antimony, etc.,	.47	"
	100.00	per cent.

The galena is in lumps with very little fine stuff. There are several other minerals occurring with it of which the following were detected: Iron Pyrites, Sulphur, Zinc Blende, Quartz, Chalcopyrite, Blue clay, Tetrahedrite, Feldspar. Only a small quantity of Tetrahedrite was found, not more than two or three grams in looking over 225 lbs. of ore.

A quantitative analysis of a sample taken from 225 lbs. of the galena is as follows: —

SiO_2,	8.56	per ct.	SiO_2,	8.56	per ct.
Lead,	49.42	"	Galena,	57.06	"
Silver,	.34	"	Silver,	.34	"
Copper,	.78	"	Copper pyrites,	2.27	"
Iron,	8.17	"	Iron pyrites,	14.87	"
Alumina,	1.70	"	Ferric oxide,	.63	"
Zinc,	8.33	"	Alumina,	1.70	"
Sulphur,	20.47	"	Zinc blende,	12.43	"
	97.77	per ct.		97.86	per ct.
Undetermined arsenic, anti'ny, water,	2.33	"	Undetermined,	2.14	"
	100.00	per ct.		100.00	per ct.

Experiment 1st. To Smelt Winamuck galena in the Reverberatory furnace by the Flintshire method.

This process consists of two parts; the ore is first roasted to convert a considerable proportion of the galena into sulphate and oxide of lead; and secondly, the heat is raised, causing the sulphate and oxide of lead to react upon the still remaining sulphide of lead, whereby metallic lead is liberated and sulphurous acid gas is disengaged. The method yields a slag very rich in lead, which is subsequently treated in a cupola furnace.

The following is an analysis of Flintshire ore.

Galena,	89.35	per ct.	
Zinc blende,	.99	"	
Oxide of lead,	5.15	"	Metallic lead, 82.71 per ct.
Lime,	.65	"	
Ferric oxide,	.29	"	
Alumina,	.13	"	
Carbonic acid,	1.62	"	
Insol. residue,	.85	"	
	99.63	per ct.	

The resulting slag contained 50 per cent. lead.

To apply this method to such an ore as Winamuck galena seemed rather hopeless, still it was thought that by taking more time a reduction to metallic lead might be effected; at all events it would show what the furnace would do. The furnace hearth is $4' \times 5'$ with a slope from all points to the tap hole. The following is the narrative of the experiment: —

Furnace fired at 9.15 A. M. with Cumberland coal. At 10.15 the furnace being at a dull red heat, a charge of 100 lbs. of finely powdered galena was introduced, the galena covered the bed with a layer 1″ to $1\frac{1}{4}$″ deep; the roasting was continued until 4.30 P. M. A sample was taken every hour to show the rate of desulphurization. These samples were afterwards tested with the following results.

	Per ct. sulph.		Per ct. sulph.
Galena before treatment,	20.47	No. 4, after 5 hrs. roasting,	8.75
No. 1, after 2 hrs. roasting,	13.26	No, 5, " 6 hrs. "	7.65
No. 2, " 3 hrs. "	11.87	No. 6, slag after fusion,	2.30
No. 3, " 4 hrs. "	10.10		

The next morning fire was lit at 9.30 and was urged as much as possible. At 12.30 the charge had assumed a semi-liquid and an air blast was now put on under the grate, 20 lbs. sulphate of soda were added to aid in the fusion, 10 lbs. of scrap iron were added to separate metallic lead; but all was in vain. At 5.30 the firing was stopped and the charge withdrawn. The failure to produce any metallic lead was due to the fact that the ore contained just enough lead to make a flintshire slag and none to spare. The resulting slag was much the same as the Flintshire gray slag, containing, however, a little less lead.

Pb = 45 per cent.
S = 2.3 "

Experiment 2d. To smelt Winamuck carbonates and the rich slag from Expt. 1st, with tap cinder and a little galena in the cupola furnace.

The furnace measures eight feet from tap hole to feed door; the interior cross section measures twelve by eighteen inches. The tuyere in the rear is seven inches above the tap hole.

The blast is fed through a $\frac{7}{8}$ inch tuyere and is of a pressure equal to $\frac{1}{2}''$ of mercury. The fuel used was gas coke. In all furnace work of this character it is all important that the slag should be of such a composition that it may be melted easily and after melting to run liquid. Hence it is all important for the smelter to ascertain from the materials at hand, the proportions most efficient to produce a liquid slag, which shall not be so basic on the one hand as to choke the furnace with salamanders, nor so acid on the other hand as to become viscid and stiff as soon as it appears outside the furnace. The slag in this instance was planned to have

Silica,	30 per cent.
Ferrous oxide,	50 "
Alumina,	20 "

Which corresponds to the formula,

$2(Al_2O_3)\ 7(FeO)\ 5(SiO_2)$.

And the mixture used for each charge was: —

Carbonates,	25 lbs.	
Slag from Expt. 1st,	$6\frac{1}{2}$ "	
Tap cinder,	25 "	
Galena,	$3\frac{1}{2}$ "	
Coke,	8 "	= 2 shovels.

Narrative of the experiment: — A fire was lit the night before to dry and heat the furnace. In the morning put blast on at 9 A. M., first ore charge at 10.35; charged every fifteen minutes. At 11 A. M. the first lead appeared; from this time on the lead and slag were tapped every ten to fifteen minutes. The furnace passed through various vicissitudes during the day none of which were very encouraging. About 6 P. M. the furnace became hopelessly constricted, and on tearing down the front a salamander about ten inches in diameter of aggregated metallic iron was found. This result proves that the slag was too basic. However, the composition of the tap cinder was not perfectly known and this error is probably enough to cause the failure. This slag carried 6.33 per cent. of lead.

Experiment 3d. To smelt Winamuck carbonates and a

small proportion of galena with lead slag from Expt. 2d and so much tap cinder and lime as to produce a double silicate slag FeO, CaO, 2 (SiO_2).

This slag would contain,

Silica,	48.4 per cent.
Ferrous oxide,	29 "
Lime,	22.6 "

The proportions for the charge were: —

Carbonates,	25 lbs.
Lead slag,	25 "
Tap cinder,	1 "
Lime,	7 "
Coke,	½ hod.

The trial was a failure. It will be unnecessary to describe its details. The slag was so acid and viscid that it could hardly be made to run from the furnace. It seems evident from these experiments that basic slags will have to be used in this furnace. The radiation of heat is very large, while the heating power is comparatively small. Basic slags are much more fusible than acid ones.

Experiment 4th. To smelt a mixture of Winamuck carbonates and galena in the proportion of 2 : 1 by weight. Fluxes to be magnetic iron ore and lime, mixed to produce a monosilicate slag.

3(FeO) CaO 2(SiO_2).

This formula would require,

Ferrous oxide,	55 per cent.
Lime,	15 "
SiO_2,	30 "

And an allowance also of iron to desulphurize the galena.

The charge used in the furnace was: —

Carbonates,	12 lbs.
Galena,	6 "
Magnetite,	12 "
Lime,	3 "
Coke,	8 " = 2 shovels.

Narrative of the experiment: — The furnace was warmed and dried by a fire the evening previous. The first charge of ore was put in at 10.35, charged every fifteen minutes. At 11.57 lead appeared. At 1 P. M. finding that the slag was too basic, the amount of twelve lbs. of magnetite per charge was reduced to eight lbs. By 2.40 P. M. having used this charge six times the slag became so stiff as to render it almost impossible to tap the furnace. Two lbs. of sulphate of soda were now added, and helped matters considerably. At 4.30 the charge was changed so as to contain ten lbs. of magnetite, and with an addition of ten lbs. of foul slag which was made during the early part of this run. The furnace was soon running finely giving a good ingot of lead and clean slag at every tap. This continued during the rest of the run. The material in the furnace stood at about 3′ 7″ deep. At 8.30 P. M. stopped charging. At 10.30 P. M. took off blast. Material in the furnace was 1′ 6″ deep, tore down the front and raked out the residue. The furnace was in better condition than after the previous run, there was a small scaffold on the back side. The slag contained 1.34 per cent. of lead. Unfortunately but a partial analysis of this slag has been made.

Silica,	34.27 per cent.
Ferrous oxide,	35.28 "
Lime,	7.10 "

This slag contained but 1.5 per cent. lead, and its composition differs largely from the above plan.

The old proverb "we learn by our failures," is doubly true of this laboratory. I think that any practical metallurgist will at once recognize the advantage to a student of a study like the one just described. Another sample of laboratory work is here given.

A silver lead ore worked by Mr. F. H. Jackson. This ore is from the 2d vein that is intersected by the Burleigh tunnel, which is situated near Georgetown, Colorado. The ore was examined for its mineral species. The following minerals were discerned: — Galena, coarse and fine grained; zinc

blende (black); pyrites, mostly granular; chalcopyrite; feldspar; mica; quartz.

The galena, zinc blende, and pyrites formed the greater part of the ore, the galena being by far the predominating mineral. From inspection of the ore it was evident that it would be advisable to separate the galena into one portion fit for smelting; the zinc blende into another to be treated by chlorinating roasting followed by amalgamation in a tub; and lastly the dust resulting from crushing, etc., which would contain too much galena for amalgamation and too much zinc for smelting. This dust it was thought might be treated successfully by gas chlorination, followed by a leaching with salt or hyposulphite of soda. The method of ore dressing had to be planned therefore to prepare the ore for three distinct metallurgical operations. The weight of ore taken was 476 lbs. 14 oz. It was at first sorted, making on the one hand a heap of pure galena, and such pieces as contained galena and pyrite, but in every case free from zinc blende. The other heap was made up of pieces containing zinc blende and other minerals.

(A.) The galena portion weighed 144 lbs. 14 oz.
(B.) The zinc blende portion weighed 331 lbs. 2 oz.

The portion (B) was crushed in a Blakes crusher set at $\frac{3}{8}$ of an inch, and sized with sieves and made ready for jigging. That which passed through a sieve of twenty meshes to the inch was saved in a separate portion, it being too fine for successful jigging. The sizes which were obtained by the sieves were

Grains which passed $\frac{3}{8}''$ sieve but remained on $\frac{1}{4}''$ sieve.
" " " $\frac{1}{4}''$ " " " " $\frac{1}{8}''$ "
" " " $\frac{1}{8}''$ " " " " $\frac{1}{20}''$ "

The jigging was performed in a sieve one foot in diameter suspended from a long wooden spring, the sieve being in a tub of water. The operation of jigging consists in placing the mixed ore upon the sieve; the sieve is shaken up and down, being kept under water at all times. By this means at every jerk downwards of the sieve, the ore particles are all of them

allowed to fall through water; the heavier invariably sink faster than the lighter. When the jerks have been repeated a sufficient number of times, the whole of the heavy ore will be found underneath while the light parts will be found on top. By this means an almost perfect separation of ore from gangue may be effected. Each of the above mentioned sizes was jigged by itself, for it is not desirable to treat all sizes together, as a large lump of a lighter mineral will settle as fast as a small lump of a heavier mineral. When the portion (B) was jigged four distinct layers were obtained. Gangue, blende, pyrites, and galena. In scraping out the sieve however, the division was made into two portions

(C.) Gangue, Zinc blende, and pyrites, 79 lbs. 2 oz.

(D.) Pyrites and Galena, 187 lbs, 2 oz.

Of that portion which passed through $\frac{1}{20}$ inch mesh sieve, the coarser part which remained upon $\frac{1}{40}$ inch mesh sieve was treated upon a Rittinger shaking table and yielded quite a clean separation of galena from zinc blende.

The results of this work may be tabulated thus

Galena smelting portion,

From hand picking,	144 lbs. 24 oz.
" the jigger,	187 " 2 "
" the shaking table,	10 "
Total,	342 lbs.

Zinc blende amalgamating portion,

From the jigger,	79 lbs. 2 oz.
" the shaking table,	12 " 15 "
Total,	92 lbs. 1 oz.

Dust for gas chlorination below $\frac{1}{40}$ inch in size, 42 lbs. 13 oz.

This investigation was not finished satisfactorily on account of lack of time.

The above will suffice to indicate the character of the work, and its value to a student whose profession will hereafter demand the solution of such problems.

Respectfully submitted,

ROBERT H. RICHARDS,

Professor of Mining Engineering.

THE INSTRUCTION IN MECHANICS AND MECHANICAL ENGINEERING.

President J. D. Runkle: —

Dear Sir: — In the Department of Mechanics the methods of Professor Rankine's work on "Applied Mechanics" have been mainly followed, this having been used as a text book, together with my printed "Notes on Mechanics." The ordinary subjects of Statics, viz., the Composition and Resolution of Forces, and the Conditions of Equilibrium, were first taken up; subsequently the subject of Distributed Forces was considered, both as applied to determinations of centres of gravity and the internal stress of bodies.

A set of models illustrative of the latter subject in its applications to tensile, compressive, and transverse strength, and also the internal conditions as to stress of homogeneous granular masses, have been employed with decided advantage.

But little time was left for the subject of Dynamics, and this was devoted to a consideration of the most important of the laws governing motion, momentum, force, energy and allied subjects, such as Moments of Inertia, Radii of Gyration, etc. The instruction is given partly by lectures, partly by recitations and blackboard exercises, and partly by the computation of numerical and practical examples, which last forms an important feature of the work in this subject.

The progress of the class was quite satisfactory, only three students having been conditioned at the close of the last school year, all of them having subsequently made up their conditions at a re-examination.

A proper knowledge of Applied Mechanics being vital to all successful progress of the student in any of the Engineering Courses, it has been, and is, the aim of this department to so arrange the work and so give the instruction that they may have a direct bearing on those subjects considered in the professional departments which depend upon mechanical laws; and, moreover, to point out as far as possible, and enable the student to keep in view and understand the methods of making the applications of the theoretical topics presented for his consideration. The plan of the instruction, therefore, involves the discussion of the applications of statical and dynamical principles immediately after, and in connection with, the principles on which they depend. A few of these subjects are the following:

1. The methods of determining the stresses in the different parts of a structure; in beams and in columns under given loads; and the mode of distribution of these stresses in the single pieces; also the forces acting on the moving pieces of machines, such as connecting rods, wheels, shafts, etc., both in regard to the motion produced and the stresses acting in the pieces themselves.

2. Methods of determining the thrusts in arches, retaining and reservoir walls, etc.

3. Determination of the momentum and energy of moving bodies, either pieces of machinery or not, and other kindred subjects.

It is hoped by this means to so familiarize the student not only with the theory, but also with the mode of readily applying mechanical laws, that he may find in his Mechanics a ready tool with whose use he is familiar, and which he can apply with facility and judgment to any of the investigations he is required to make in his professional work, either at the Institute, or hereafter.

The adoption of the new scheme of studies last session could not at the time much affect, in this particular subject, the condition of a class as far along as their Third Year; but in the present year the three following consequences of the scheme promise to aid materially in carrying out more fully the plan already laid down.

1. The Calculus, instead of being studied contemporaneously with the Mechanics, is completed before the Mechanics begins; hence the student does not have his attention divided between these two serious studies.

2. The parts of the Calculus used in the Mechanics are already known by the students, so that they are not obliged to stop and devote part of the time that belongs to the Mechanics in studying the mode of performing the necessary Calculus operations.

3. The number of exercises, though not materially increased as a whole, has been made three per week instead of two, as heretofore.

These changes must inevitably aid in a decided manner the fuller carrying out of the above scheme. I would further suggest that it would be extremely desirable, whenever it is possible, and there are no special reasons to the contrary, that such subjects in the professional departments as depend directly on, and involve the applications of, mechanical laws, should be treated by the department at such times as the students are considering in their Mechanics the theories involved; also that experiments bearing on such subjects should, as far as possible, be made at the same time in the laboratories, as it is believed that approaching a subject at the same time from different points of view is conducive to a more thorough understanding of it on the part of the student.

Such an arrangement has been made in the department of Mechanical Engineering, and in whatever other department it should be found practicable to adopt such a system, it could not but infuse a new life into the interest taken by its students in their Mechanics, besides saving more or less a repetition and

review on the part of the professional department of the modes of applying the mechanical laws to the practical cases, before being able to proceed with the purely professional work depending upon them.

I would also submit that whenever the previous preparation of the students shall warrant the completion of the Calculus in the second year, and allow the Mechanics to be studied three times per week for the whole of the Third Year, the degree of completeness with which the scheme already laid down can be carried out will be even further increased.

The work done in the Mathematical part of the Mechanical Engineering Course during the last school year was as follows: in the Fourth Year's Class the subjects studied were Dynamics of Machinery, Strength of Materials, and Thermodynamics; in the Third Year's Class, Mechanism and Thermodynamics; in the Second Year's Class, Mechanism.

Professor Rankine's treatises on Machinery and Millwork, and on the Steam Engine, were used as textbooks, and the above subjects were taken up in the order followed in these works: thus in the Dynamics of Machinery the laws governing Momentum — Energy and Work of Machines and parts of Machines were first considered. Subsequently the subject of Friction, and the work used in overcoming it, the efficiency and counterefficiency of Primary pieces and of modes of connection in Mechanism were discussed, and also the subjects of Brakes, Dynamometers, Indicators, Flywheels, Governors, etc.

In the Thermodynamics the greater part of Chapters I, II, III, and IV, Part III of Rankine's Steam Engine were studied; the following being a part of the subjects discussed, viz: Thermometry and Calorimetry, Absolute temperature, Specific heat, real and apparent, Sensible, Latent, and Total Heat of expansion, evaporation and fusion, Efficiency of furnaces and boilers; Evaporative power of fuel, Total Heat of combustion of fuel and Draught of Furnace, Isothermal and Adiabatic lines, Potential and Thermodynamic functions, Indicator diagrams of jacketed and of unjacketed cylinders, Efficiency of steam in the

cylinders, Properties of Saturated and Superheated steam, etc., etc.

In the Strength of Materials Part III of Rankine's Machinery and Millwork was studied, and such explanations and illustrations given as seemed necessary for a full understanding of the subject. The Third Year's Class in Mechanism completed the greater part of Part I of the Machinery and Millwork; and the Second Year's Class took up the subjects of Cams, Connection by Bands, Linkwork, Reduplication, and Hydraulic connection. The same subjects are presented at the same time to the student in this and in the other three parts of the Mechanical Engineering course, viz., the Practical, the Graphical and the Excursional; and he is made to approach them from a different standpoint in each. This system keeps up the interest of the student in his work, and gives him a far greater degree of familiarity with it than he would otherwise acquire.

The instruction is given partly by lectures, recitations and blackboard exercises. But few written exercises and computations are required to be handed in in this part of the course; this belonging more particularly to the practical part of the course. Care is also taken not only to collect from Professor Rankine's other works whatever is said on any particular subject, but also to utilize all other available sources, in order to present to the class the simplest and clearest demonstrations.

Such models as the Institute is already provided with have been used with the greatest advantage, and indeed are indispensable. It is only to be hoped that their number may be increased as rapidly as possible. The progress of all the classes was very satisfactory; all the students who stood the final examinations having passed without conditions.

Very respectfully,

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REPORT OF THE DEPARTMENT OF MODERN LANGUAGES FOR THE YEAR 1873-4.

President Runkle: —

DEAR SIR: In the absence of any previous report of this department it is difficult to obtain a satisfactory idea of its past course and policy. For the following brief statements and impressions in regard to the year immediately preceding that under consideration, I am principally indebted to the tabular views in the catalogue and the examination papers.

1. *Brief review of the department for the preceding year.*

During the year 1872–3 French was taught in all the classes throughout the year, excepting in the second half of the Fourth Year. The same is true of the German, excepting the first half of the First Year. The number of exercises per week varied from one to four, rising to the latter number only in the First Year during the first half in French, and falling to the former number only in the First Year during the second half in German. The number of exercises per week, with these exceptions, varied from two to three. Taking this year as a basis, the number of exercises of an hour each a student would have during his entire course would be 270 in French, and 225 in German. These exercises were almost entirely in the form of recitations. As to the amount of time allowed or used outside of the recitation room for work, whether beforehand or afterwards, on these exercises, I am unable to obtain any exact data. What indications there are would lead to the con-

clusion that this was not very much nor very regular. The amount read, however, in both French and German, was considerable, amounting to 300 pp. or more in either language. The entire number of recitations a week varied from twenty-four in the first term to sixteen in the second. As a result the graduates have for the most part, I believe, been able to read easy French at sight, but as much cannot be said of the more difficult German. As to the accuracy and strength of the students' knowledge it would be difficult to make any statement.

With respect to the above, it should be remarked that the number of recitations, 495 in the regular course in French and German, is very large. Moreover those in German were disproportionately smaller than those in French, whereas they should be more numerous, in view of the much greater difficulty of the same and the greater time necessary for attaining the same degree of proficiency. If the impression be a correct one, that very little independent work was done by the student outside of the recitation hours, the results would indicate that such work is necessary for accuracy and strength in the practical use of these languages.

2. *Scheme for the modern languages at the beginning of the year* 1873–4.

At the beginning of the year 1873–4, it appeared that the time previously assigned to both French and German had been very much curtailed, owing to an action of the Faculty aiming at lessening the pressure of work upon the students, which had been found to be too great. On the basis of this half year as indicated by the tabular view, the entire number of exercises in the regular course would be in French 150, and in German 210, instead of 270 and 225 respectively as in the preceding year, or 360 for the entire course instead of 495 as before. Besides, it was expressly provided that no preparation should be allowed for one of the exercises, and only an hour for another. The diminished number of exercises would have sufficed, in itself considered, but the difficulty was that the students, excepting the First Year, were unable on account of the pressure of their profes-

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sional work to devote any adequate amount of time to the work of the French and German.

The entire number of recitations per week in the regular course this term were 12 in French and 10 in German, counting the repetitions on account of division of classes. In the special Italian course there were 2, making in all 24.

3. *New scheme for the French and German, being a part of the general revision of the studies of the Institute.*

Before the close of this term it was found necessary to undertake a complete revision of the entire scheme of study of the Institute. This was very carefully and deliberately worked out and put into operation, so far as possible, the second half of the year. The provisions of the same, so far as it referred to this department, were as follows. (1) But one modern language is to be taken up at a time, and this finished before another is commenced. (2) Three exercises a week for two years are allowed to each language. (3) Two hours for preparatory or subsequent work are provided for each exercise.

(1.) In regard first to the time when one language can be dropped and give place to another. Inasmuch as French is required for admission, this would naturally be continued until finished, when German would be commenced and receive the length of time assigned to it. As the requirements in French at the first examination on this subject for admission were equal to about half a term's work in the school, this language would be finished by this class at the middle of the second half of the Second Year. The requirement for admission as fixed in the catalogue for the next class being about twice as much as above, this class would be through with its French by the middle of the Second Year, and so on in proportion as the French requirement for admission may be increased. In the second case the German would be finished by the middle of the Fourth Year.

(2.) In regard to the length of the course and frequency of the exercises. A smaller number of exercises per week than three, especially at the beginning, would, it is thought, fail of se-

curing such a concentration of the student's attention upon his work as is to be desired. This number, however, would secure that object and produce probably the best proportionate results, being at the same time consistent with the student's exercises in other departments. Three exercises a week for two years give a course of one hundred and eighty exercises. This number is smaller than that allowed the German the first half of the year in question, and much smaller than that allowed either language last year. It happens to be exactly the same length as the course in each of these languages at another prominent and well-established scientific Institution, except that there the time at the student's command for previous and subsequent work is somewhat greater. A course of this length prosecuted in the manner indicated should, it would seem, enable a student to translate ordinary French at sight, with a fair amount of accuracy and strength in dealing with passages of special difficulty. This would probably be too strong a statement for the German, whose construction is more involved, and which requires much more practice than the French. But although the time given it is no more than that given the French, it should be said that it is taken up after the student has had the training in language afforded by the latter course. It is to be understood that this scheme has reference principally to the regular courses for all students. The Science and Literature and optional classes would naturally be treated more or less differently. The former for instance, where the course in French and German is more of a literary and philological character, might have more time allowed them; while the latter, where the object is principally practice and the acquisition of a vocabulary, could pursue advantageously a course of two exercises a week without being called upon to do any outside work.

(3.) The final and perhaps most important point of this scheme to be considered is the time assigned for work outside of the recitation room. This has reference partly to the rapidity of the student's progress, but more especially to the character of the work done. A very considerable part of the recitation

sional work to devote any adequate amount of time to the work of the French and German.

The entire number of recitations per week in the regular course this term were 12 in French and 10 in German, counting the repetitions on account of division of classes. In the special Italian course there were 2, making in all 24.

3. *New scheme for the French and German, being a part of the general revision of the studies of the Institute.*

Before the close of this term it was found necessary to undertake a complete revision of the entire scheme of study of the Institute. This was very carefully and deliberately worked out and put into operation, so far as possible, the second half of the year. The provisions of the same, so far as it referred to this department, were as follows. (1) But one modern language is to be taken up at a time, and this finished before another is commenced. (2) Three exercises a week for two years are allowed to each language. (3) Two hours for preparatory or subsequent work are provided for each exercise.

(1.) In regard first to the time when one language can be dropped and give place to another. Inasmuch as French is required for admission, this would naturally be continued until finished, when German would be commenced and receive the length of time assigned to it. As the requirements in French at the first examination on this subject for admission were equal to about half a term's work in the school, this language would be finished by this class at the middle of the second half of the Second Year. The requirement for admission as fixed in the catalogue for the next class being about twice as much as above, this class would be through with its French by the middle of the Second Year, and so on in proportion as the French requirement for admission may be increased. In the second case the German would be finished by the middle of the Fourth Year.

(2.) In regard to the length of the course and frequency of the exercises. A smaller number of exercises per week than three, especially at the beginning, would, it is thought, fail of se-

curing such a concentration of the student's attention upon his work as is to be desired. This number, however, would secure that object and produce probably the best proportionate results, being at the same time consistent with the student's exercises in other departments. Three exercises a week for two years give a course of one hundred and eighty exercises. This number is smaller than that allowed the German the first half of the year in question, and much smaller than that allowed either language last year. It happens to be exactly the same length as the course in each of these languages at another prominent and well-established scientific Institution, except that there the time at the student's command for previous and subsequent work is somewhat greater. A course of this length prosecuted in the manner indicated should, it would seem, enable a student to translate ordinary French at sight, with a fair amount of accuracy and strength in dealing with passages of special difficulty. This would probably be too strong a statement for the German, whose construction is more involved, and which requires much more practice than the French. But although the time given it is no more than that given the French, it should be said that it is taken up after the student has had the training in language afforded by the latter course. It is to be understood that this scheme has reference principally to the regular courses for all students. The Science and Literature and optional classes would naturally be treated more or less differently. The former for instance, where the course in French and German is more of a literary and philological character, might have more time allowed them; while the latter, where the object is principally practice and the acquisition of a vocabulary, could pursue advantageously a course of two exercises a week without being called upon to do any outside work.

(3.) The final and perhaps most important point of this scheme to be considered is the time assigned for work outside of the recitation room. This has reference partly to the rapidity of the student's progress, but more especially to the character of the work done. A very considerable part of the recitation

room exercises, such as practice in pronunciation, learning new words, becoming familiar with forms, and practice in translation can be done as well by the student alone, after he has received specific directions with illustrations in regard to the above. An allowance of time therefore for work outside of the recitation or lecture room necessarily accelerates his progress to a corresponding degree. But of more importance than this is the consideration that the character of his knowledge is largely dependent upon the student's unaided work by himself. There is a strength in the knowledge and use of a language gained by working out a translation alone which can be gained in no other way. Thus the student is forced to decide why this must be so, and why it cannot be otherwise, either by searching for and comparing other similar cases or examining the law in the grammar. Besides, when for the sake of acquiring words and fluency in the use of the language, easy French or German is read to the class in the recitation room, the full and proper results of such an exercise are only secured when the student has subsequently gone over by himself what he has followed in the class room. But to require such outside work in the study of the languages is apt to be looked upon with suspicion, as it is so often misused for the memorizing of disconnected grammar rules, or even a too minute or extensive attention to the analysis or construction to the sacrifice of the thought. But when the time is legitimately used, as hinted at above, the bearings of the work are recognized, and there is no reason why it should not be agreeable, and not an irksome task. The ability to comprehend a foreign language with readiness and accuracy is an acquisition of no slight value, and in this as in other departments of science the value of the results is apt to correspond pretty closely with the work required in order to attain them. However much a proper method may facilitate the accomplishment of the object in view, much time and work is indispensable.

4. *General views in regard to the instruction in the modern languages.*

In connection with the above scheme it is desirable to con-

sider also by what general method the student can best pursue his study of a modern language. Shall it be (1) the rote or practice method, such as a child pursues in learning its mother tongue, or the similar so-called Ollendorff method; or (2) what we may call the *à priori* or dogmatic method, such as is generally pursued in the study of the dead languages; or (3) a mean between the two combining the excellences of both, while avoiding their defects. We think decidedly the latter.

For what is the object in view? It is to learn to *read*, with *accuracy* and *readiness* a scientific work in French or German. Accuracy and readiness, theory and practice, both are essential, but they must be in due proportion. To proceed as a child does in learning its mother tongue, although such a course if continued long enough would undoubtedly produce a satisfactory result, is neither necessary nor practicable. Developed powers of judgment and thought give him an advantage over the child, not only with regard to the point at which he can take up the subject, but also the manner of pursuing it. Why not take up at once the actual text and apply his powers of observation and the principles of induction, being assisted in learning the laws of the language both by the teacher and the embodiment of the same in the grammar. Talking is not his object, although conversational exercises will prove of assistance in making him familiar with the laws and idioms, and in learning words. Should he visit the country where the language is used, in which case alone he will have occasion to speak it, that facility will follow readily, as experience can testify. Facts also prove that he can enable himself to comprehend accurately and readily the page of a foreign writer, although he might not be able to hold a conversation in the same language. This is all he needs, and it is not consequently necessary to consider the more psychological than philogical or practical question, as to whether a person can read intelligently a foreign language, who cannot speak it or think in the same. But practically his other engagements are such that he cannot devote a large amount of time at frequent intervals,

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as would be necessary if he were to learn another language just as he learned his own. Moreover, there is serious danger that this purely practical method, in itself considered, will fail of being a permanent acquisition, coming as it does from practice, and dependent upon constant practice, just as Americans, who have learned in a very short time to speak by rote the language of a foreign country, upon returning are deprived of their practice and soon lose their power of either speaking or reading. Practice in reading alone might not require so much time, but it would be equally open to the objection just mentioned.

Nor, on the other hand, is the method currently used in the study of the dead languages adapted to the end in view. That involves too much anatomical work, and fails to give the necessary practice and readiness in appreciating the thought of the author. It is open to the charge of studying the grammar, etymology and logic, too much, but the language, too little, which, though it might be defended with a purely educational end in view, cannot be where the object is a practical one. This system sacrifices the practice and favors the theory, the former favors the practice and sacrifices the theory.

But a mean between these two extremes seems best adapted to conduct the student most surely and expeditiously to his object, which is to read understandingly and readily. He should have the practice and attention to the thought of the author on the one hand, and on the other such a systematic knowledge of the main laws of the language as will ensure him strength and accuracy in interpreting its authors, and which being thus fixed in the mind will never be forgotten, though the practice should be intermitted. In a word, the student should from much practice acquire a practical readiness in appreciating the thought of the writer on the one hand, and on the other such a survey and comprehension of the structure of the language, as will make his acquisition a permanent one, and one enabling him to meet with strength serious difficulties of interpretation.

In practically carrying out these views, the actual text of the foreign language in some form has been presented to the student from the outset for his practice and study. In connection with this the forms have been studied and practiced, so also the principal laws and usages of the language, in the progress of the student's course. Consequently grammar, or a systematic embodiment of these forms and laws, has been a constant subject of study. Much reading gives the requisite practice, while a careful attention to the grammar or laws of the language not only facilitates the acquisition of the same, but ensures the student accuracy, and the permanency of this acquisition. But it is very important practically to know what is understood by the study of grammar. If it means learning a number of technical, obscure expressions, or the memorizing of a body of rules or observations not in immediate connection with the living text, but which it is intended to apply to that at some future time, then it is not strange that it should be to the student a very unwelcome work, and its study seem a very irksome and unprofitable task. But if grammar means a regular induction of the laws of the language, resulting from the observation and comparison of individual cases and their systematic arrangement, then its study affords a satisfaction and sense of mystery to the student, and he is as much interested in it as he is in the laws of any science. He realizes that there can be no accuracy without these laws, and that, from the fact that he can comprehend them more quickly than the child and apply them with less practice, he progresses far more rapidly in acquiring the language. The aim has been, accordingly, constantly and regularly to call the student's attention to these laws as the text has presented them, and to use the grammar as a reference book for a fuller statement, and also a permanent one for him to refer to at his pleasure. Much importance has been attached to dictation exercises as a means of presenting these laws and affording practice on them, also of learning words, idioms, and the general spirit of the language. They have accordingly been a frequent and regular part of the work.

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In addition to the semi-annual and annual examinations, there have been intermediate examinations of an hour each on the amount gone over the preceding month. It is believed that these have been of much value, in giving the student a definite indication of his progress, while they also afford practice in writing translations, and precision in the expression of his knowledge.

After considering the shortest way, so far as is consistent with strength, permanency and accuracy, of attaining to the ability to read readily a foreign work, the thought naturally arises, what is the value of this course of training as a means of general culture. Were the latter the direct object, some modifications would perhaps be desirable, but as it is, there can be no doubt that such a course, being of a methodical nature, and having to do with the written works of other people, must exert much influence in the direction of a liberal and general culture. This consideration presents an additional reason for allowing this work an adequate provision of time, and bestowing upon it especial attention.

5. *Work done in the several classes during the year.*

FRENCH. *First Year.* In addition to exercises in especial connection with Otto's Grammar, the class read during the year fifty-nine pages in Otto's Reader and thirty-five pages in Corinne. There were three exercises a week, with two hours for preparation during the second half. *Second Year.* The French was confined to the first term, at the rate of two exercises a week, no preparation being allowed. Seventeen pages in Corinne were read. *Third Year.* The French was also here confined to the first term, at the rate of two exercises a week, with one hour for preparation on each. The "Atala" of Chateaubriand was read, or one hundred pages. In the *Fourth Year* there was no French.

GERMAN. *Second Year.* There was no German in the First Year, but the Second Year commenced this study at the rate of three exercises a week. In the second half of the year the class had two hours' preparation for each exercise, in the first half there was often no time for this, and the amount was

in general small and irregular. In addition to dictation and other exercises, fifty pages in Whitney's Reader were read. *Third Year.* Selections from German ballads, also Heyse's "Die Einsamen," eighty-eight pages. There were also dictation exercises. *Fourth Year.* Besides a few German ballads, Goethe's "Egmont" was read, making one hundred and forty pages. The class continued the study optionally through the second term with the Science and Literature class.

In addition to the above, in which all of the regular and some of the special students participated, five members of the Science and Literature and Philosophical departments pursued in the Third Year, second half, an advanced course in French, reading three plays of Molière (149 pages) with regular exercises in dictation, and the translation of longer extracts from English into French. Members of the same department in the Fourth Year, continued during the second half their German, reading the last three acts of "Egmont".

There was an optional class in Italian during the year composed of six Fourth Year students. Two hours a week were assigned to it, and the subject pursued in such a manner that no outside work was required. It would seem advisable to urge students to go farther in French and German rather than take up Italian or Spanish, in which they can at best get only an introduction. But for those, who for special reasons, as students in architecture desiring Italian, or those in engineering expecting to go to Spanish-speaking countries, the best arrangement would seem to be, to have classes in these languages on alternate years open to students of both the Third and Fourth Years. That would enable each graduate to pursue a course in one or the other.

The time assigned in the second half of the Fourth Year to a course in the Science of Language, for students in the departments of Science, and Literature and Philosophy, it was impossible to utilize for want of time on the part of instructors. It is hoped that so valuable a course may be carried out the next year.

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The whole number of exercises per week during the first half

year was twenty-four, during the second half twenty-three. Eight of these exercises in the first half, and six in the second half were repetitions, owing to the division of the First and Second Years.

6. *The regulation requiring French for admission.*

The regulation making French one of the requirements for admission was first put into operation at the commencement of the year of which this is a report. The amount required was "The first nineteen lessons of Otto's Grammar," that is, the elements of the language as far as regular verbs, with some practice on sentences illustrative of the same. This would be equal to at least half a term's or two month's work in the Institute. This requirement was poorly answered. The class at the beginning numbered seventy-nine, of whom thirteen had never studied French at all. The average mark in French of the whole class at admission, not including ten who had advanced much farther than the amount required, was somewhat below fifty on a scale of one hundred. There were thus three distinct divisions in the class, each demanding different treatment by themselves. The ten students advanced in French were excused entirely for the First Half Year. The thirteen who had never studied the language at all should have been enabled by more frequent exercises, and by reciting by themselves to catch up with the class, which could have been easily done by the semi-annual. But means of instruction failing for this, it was necessary that the whole, thus unequally constituted, should go on together, to the disadvantage of both, neither receiving the treatment best adapted to it. It is especially to be recommended that there should be in future such a separate class, at least until the requirements are better responded to.

The amount required in French the following year was: "Pt. I of Otto's Grammar, and the first twenty-five pages of Bôcher's Reader, or their equivalent." This is probably rather more than twice as much as the amount required at the first examination, and rather more than half a year's work at the Institute. It is to be hoped that it will soon seem feasible to increase this amount, so as to include a knowledge of the main principles of

the language and more practice in reading, so that a year's work can be done before entering, and the French as a regular study discontinued at the end of the first year.

Undoubtedly a small amount of Latin would have been easier to obtain than the French. A majority of the students study Latin before coming to the Institute, and without reference to entering it. At the High Schools, where most of them receive their previous education, Latin is a regular study, whereas French is taught, I believe, in comparatively few. It therefore becomes a serious matter of expense as well as of difficulty to obtain the necessary preparation in French, especially as it is a subject which the student cannot work up alone, as would be quite possible in the case of the Latin. It should, however, be stated on the other hand, that the colleges are now beginning to require French for admission, which will have its influence on the High Schools and others, where students prepare for the Institute. Hence it is likely to become easier each year to meet a French requisition for admission, especially should the indulgence shown candidates not prepared in French be continued, whereby they are allowed to join their class on condition of making up, by extra work, their deficiency.

7. *A modification of the present scheme in French and German proposed.*

A slight change in the scheme already arranged would make it more satisfactory, so far as this department is concerned, without affecting unfavorably any other one, so far as can be seen. As it at present stands, the German cannot be taken up before the middle of the Second Year, when the time (two years) assigned to the French will be concluded. The proposition is to commence the German at the beginning of the Second Year, and complete the remaining half year to which the French is entitled at another point in the course. The latter might be done in the first half of the Fourth Year, in which case a course of optional French reading in the interval would obviate the difficulty of so long a suspension of the language. Or the same object might be accomplished by allowing the French an additional number of lessons a week the First Year,

which seems to me the better plan. The regular course in French would thus be secured, and on the other hand that in German would be greatly improved. For, in the first place, the strictly technical German, which is much more difficult than the strictly technical French, can be advantageously learned only in the departments needing it, and with the assistance of the Instructors there; in order to which, however, the study should be commenced, at least, as early as the beginning of the Second Year. In the second place, the German, being a much more difficult language than the French, and demanding much more practice, should have a place in the course where it can be pursued seriously and without interruption. But students in the Fourth Year, being closely confined to their professional work, would be in danger of failing to give it the time and attention which it could have the year before. Moreover, if the regular German course were finished at the end of the Third Year, there would be left an entire year for an optional course in practice-reading in the same, occupying but two hours a week of his time, and which would be of great value in increasing his vocabulary and facility in recognizing the thought of the writer. Besides, it would then be possible to extend over the whole Fourth Year the literary and philological course of the Science and Literature students, which now has but half the year. It seems also especially desirable to make such a change in behalf of the German, since this language, as it now stands, does not receive so much attention as the French, and students have not consequently attained the same proficiency in it as in the latter. Even with this change made, it is hardly possible that students will be able to reach the same point in German as in French.

In addition to the above, I would propose a course of optional practice-reading of a year each, in both French and German, which, in regard to the latter, has just been alluded to. The object would be to enable the student to increase his vocabulary, and require additional readiness in following the thought of a writer. Popular presentations of various branches of science in French and German would in part, at least, af-

ford profitable texts for such reading, although strict scientific treatments of subjects, especially in German, should be taken up by the students in the several departments with the help which they would receive from their Instructors and laboratories. Such a course should come at the conclusion of the regular one, when students are able to read at sight, even though hesitatingly, easy French and German. The best place for that in French would be in the Third Year, or better, in the Second, should that not be too much crowded; and for that in German in the Fourth Year. This course might consist of two exercises a week, no preparation on outside work being required or expected, and it being optional with a student, according to the time he may have at his disposal, to take it up or not, it being understood, however, that if he do begin he is to attend punctually, and pass the usual intermediate and annual examinations.

With arrangements as suggested above, the Science and Literature, and Philosophy students, would have the entire Third Year for an advanced course in French, and the Fourth Year for an advanced course in German. They would also have, as at present, the Second Half of the Fourth Year for the course in the Science of Language, intended to consist of familiar presentations and discussions with regard to the nature of language, its life and growth, the place its study occupies among the sciences, the separation of languages into dialects, the characteristics of the great families into which human speech is divided, and, finally, the question of the origin of language; these subjects being considered as much as possible with reference to the English, and illustrated by examples from the same.

The Italian and Spanish optional courses would continue as above indicated.

With expressions of sincere appreciation, Mr. President, of your constant and very valuable support of the management of this department the past year, the above is

Respectfully submitted.

C. P. OTIS.

THE INSTRUCTION IN INDUSTRIAL AND PHYSIOLOGICAL CHEMISTRY.

President Runkle: —

Dear Sir: — As the number of our students has increased from year to year, the repeated demands for more room for chemical manipulation and analysis, and for metallurgical work, have been but insufficiently met by extending the laboratories so as to take up all the available space in the basement of the building. Other departments have also felt the need of an extended area, and in this continual struggle for space the less elementary branches have been compelled to yield. Hence the subjects which come under my special charge, industrial and physiological chemistry, still lack a local habitation, and many long felt wants remain unsupplied. But we invite students in advanced and special chemistry, and in order to keep up the rank which we have hitherto held among schools of science, it is important that laboratories should be established for the instruction of such students. For instruction and for research in chemistry, as applied to the arts, we should have facilities for operating on pounds of materials instead of grains, and there is needed apparatus similar to what is actually in use on the large scale. One who has worked only with test tubes, watch glasses, beakers, platinum crucibles, and small gas burners, is ill fitted to make such practical experiments as are required for the improvement of manufactures, and he necessarily feels much at a loss when brought in contact with the operations of real life.

There should be a *Laboratory of Industrial Chemistry*, affording room to work with tubs, stoneware jars, bag filters, large retorts, furnaces, and steam kettles. Connected with it there should be a *crystallizing room*, cool, and free from dust.

Such a laboratory is not for the industrial chemist only. Students who have to engage in special researches, whether practical or purely scientific, often find it necessary to prepare in the first place the chemicals required, for they are not to be found in commerce, or the shops afford them of unsuitable quality. The laboratory of analysis is no place for such manufactures, and lacks apparatus suitable for making the quantities required.

He who studies the proximate analysis of organic substances, or the synthesis and the metamorphoses of carbon compounds, must operate on comparatively large amounts of material, and on account of such needs, at least one room should be set apart as a *Laboratory of Organic Chemistry*.

Methods of analysis, synthesis, and transformation, have been latterly coming much into use, which involve the heating of substances in closed tubes and under high pressure. Of course there will sometimes be explosions, which not only scatter glass at random, but also diffuse suddenly through the whole room unpleasant or noxious vapors. Such things must needs disturb the equanimity of students quietly engaged in ordinary analysis, and the rapid and thorough ventilation which is suddenly called for, proves inconvenient where a large number are busy with nicer operations. The good of the greater number must therefore be sacrificed occasionally unless there is a special *room for high pressure experiments*.

The chemist who is restrained by wooden floors and tables from using combustible fluids finds the paths of investigations very much hemmed in, and longs for a vaulted room in which he can distil a few ounces of ether or benzole without watching his retort every moment with a hydrant hose in hand. *A fire proof room* prevents such anxiety, and much waste of time.

A special *room for gas analysis* should be added to the ordinary analytic laboratory.

That part of chemistry which relates to the growth of plants and animals is by no means of subordinate importance. And it has been felt that a professedly liberal course of education must be incomplete when physiology and biology are left out of account. Therefore in rearranging our courses of study, it was deemed proper to include botany and zoology as in themselves useful and as laying the foundation for that higher branch of chemistry which relates to the vital operation of living organisms. Hitherto the instruction in all these branches has been given by lectures or recitations, with the help of such specimens as can be conveniently handled in the class-room. But all science teaching is defective, which does not take in laboratory or field work on the part of the student himself. Experiments in germination, fermentation, respiration, diffusion, assimilation, and the like, need facilities for the exact and continued regulation of light, heat, moisture, and surrounding media. *The Physiological laboratory* then must have its peculiar arrangements differing greatly from those of the work-rooms already mentioned.

In the study of animal and vegetable chemistry much use is made of the microscope and the spectroscope. *An optical room* and an *apartment for dissections* are, therefore, essential adjuncts of the physiological laboratory.

If any one fails for the moment to understand why the chemist should extend his studies into the domain of Natural History, let him consider how many phenomena, which fifty years ago were set down as simply owing to some abstruse chemical action, are now found to be intimately connected with the development of cryptogamic growths. Let him remember, that in the examination of natural waters with reference to domestic use, the microscope often makes important revelations when chemical analysis fails to give satisfactory indications. Let him reflect that in studying the adulterations of food, drugs, textile fibres, and so on, the microscope is indispensable. So there are many matters that a chemist may be called to report upon, which are extra chemical and which the mere chemist is incompetent to investigate. It is indeed true, that in looking the

world over, we very rarely find physiological laboratories connected with schools of science. But how few years is it since even physical laboratories came into existence; and yet, who would now think an institution for scientific teaching to be complete without a physical laboratory? I believe the time is not very remote, when there shall be a like feeling with regard to the physiological laboratory.

A much felt want is that of a *working library room*, light, dry, airy, and clean, in which may be gathered books of reference, monographs and details of researches in chemistry, biology, microscopy; and this room should be provided with tables for writing and drawing, and with racks for charts and diagrams. The chemical department has, at present, no fit place for the few books and periodicals which we possess, and it can offer no shelves on which the Professors may place often consulted works from their own private collections, without fear of injury.

Shall I weary you by going on to say, that the use of class-rooms in common with other departments admits of no special adaptation to our particular requirements and gives little opportunity to prepare for lectures which should be enlivened by the exhibition of specimens, drawings, or projected images of actual tissues?

Excuse me for reminding you how straitened we are for room, when you call for a report on condition and progress. As to what has been accomplished during the past year, I can only say, "we have left undone many things that we ought to have done" and have done simply what we could. In respect to industrial and physiological chemistry, and botany, without even asking receiving an appropriation we have gone on providing out of limited private means what was needed for the daily instruction, and have been gradually securing apparatus, specimens, charts, and books with reference to future work, hoping that the time will come when there shall be places for these things and room to work in.

Respectfully yours,

JOHN M. ORDWAY.

THE DEPARTMENT OF PHYSICS.

President Runkle:—

Dear Sir:—Since the presentation of the last Report of the Physical Laboratory several important changes have been made both in its organization and in the facilities offered to the student. With the establishment of Physics as an independent Department, a Four Years' course is offered to a student who wishes to make a specialty of this subject, either to teach it, or for its applications. Like the Departments of Philosophy and Science and Literature, the course is also designed for those wishing an education of a less professional nature, but unlike them, the scientific studies are rendered more prominent than the literary. The exact course of study offered is detailed in the Catalogue and need not be repeated here, but it will be noticed that it combines most of the studies, not of a strictly professional character, of both the Engineering and Chemical departments. It differs from them mainly by the introduction of several special courses, including Photography, Lantern Projections, Electrical Measurements, Microscopy, Spectroscopy, and other advanced physical work.

The exercises in Physics given to all the students during the Second and Third Years are substantially the same as before, and it is not probable that any changes will be made in them except in details. All the lectures on general physics will now be given during the Second Year, instead of partly in the First Year as heretofore, and both the lecture and laboratory courses have been improved by the purchase of additional instruments.

Prominent among the latter are a Holtz machine and Induction coil, the want of which has heretofore been seriously felt.

The exercises in Photography consist in part of lectures, giving the theory and description of the most important processes and their applications, and practical exercises in which each student shall perform the whole work of taking photographs himself. A student can become a really skilful photographer only by long practice, but in a short time, if properly taught, he may obtain very good results and will be saved much time and money if he begins his work in the presence of some one who can point out his errors, and show him how to correct them. Otherwise, he may simply obtain poor pictures and be unable to decide what is the difficulty. Students will be taught to take both negatives and positives, special attention being paid to the former as the basis of almost every photographic process. They will then learn to take positives on glass suitable for projection in the lantern, and paper prints. As subjects they will employ mainly such as have a scientific value, as drawings and apparatus, and later, microscopic objects, spectra and other more difficult objects.

A course of Lantern Projections was given last year with results that justify its introduction as a permanent part of the course. The theoretical principles involved are given in the form of lectures, and each student then learns to perform the various experiments with the lantern, such as projecting photographs, chemical and electrical decompositions, opaque objects, spectra, using the vertical lantern and other applications of this most useful instrument. The method of making the calcium and other brilliant lights is also taught, and the method of measuring their intensity photometrically. The aim throughout is to enable the student, if required to deliver a course of lectures, to illustrate them fully by the lantern.

Another course tried for the first time during the past year is that entitled Advanced Physics. The object of this course is to supplement the other exercises and supply a place where any matter which a student should know may be properly in-

troduced. Its special object is to furnish the information ordinarily required by a scientific man from societies and periodicals. This want is met in some institutions by scientific societies among the students, but the objection to them is that a portion only of the students are in general interested, and of them most of the work is generally done by two or three. Moreover, although they may be started with much enthusiasm the interest often flags, and they are neglected for the regular studies of the school or for other duties. In the present case on the other hand attendance is required, as at any other exercise of the school, and special subjects being assigned to each student, all take part. During last spring a series of exercises of this kind was held, and eight students took part in them. One of the class was each time asked to act as Secretary, and took notes which he afterward copied and read at the beginning of the next meeting. Another student was then appointed in his place, and their notes form a permanent record of the work done. The meetings were attended with great regularity and the interest was well sustained. Some of the papers were original, but in many cases a subject was assigned to a student on which he prepared a paper, and presented it to the class. All the papers were illustrated, as far as possible, by experiments prepared by the student, who in some cases, also made the apparatus.

Among the papers were the following:—

Forms of Water in Clouds. Mr. F. H. Very.

Sternberg's Heat-registering Apparatus. Mr. S. J. Mixter.

A Fire-escape. Mr. C. F. Howard.

Pendulum Curves. Mr. C. A. Morey.

Zöllner's Horizontal Pendulum. Mr. T. H. Sampson.

Self-registering Barometers. Mr. S. J. Mixter.

Artificial Flight. Mr. C. A. Morey.

An Optical Dynamometer. Mr. W. O. Crosby.

Divisibility of Matter. Mr. S. J. Mixter.

Lippman's Capillary Electrometer. Mr. T. H. Sampson.

An improved Phonautograph. Mr. C. A. Morey.

During the past autumn a partition has been erected along the further wall of the Laboratory and small rooms thus formed for some optical and electrical experiments which are best prepared in the dark. This change is found to be a great improvement and to add materially to the available space. It is a step in the direction long advocated by the writer of employing a number of small rooms, instead of one large one for a physical laboratory. The manuscript of directions for performing a number of electrical experiments has been prepared, and through it much work has been done by the special students in physics in the measurement of absolute electrical resistances, currents and electromotive forces. An admirable practical application of this work has occurred in the tests now in progress of a large magneto-electric machine loaned to the Institute by its maker, Mr. M. G. Farmer. It is greatly to be desired that this machine may be secured permanently for the Institute, as its value would be very great in many ways. First, it would furnish a current of electricity of sufficient magnitude to produce an intense light which could replace the calcium light and might be used for lighting the large hall. Secondly, it opens a broad field of experiment for the students in almost every branch of physics. In mechanics it affords an extremely easy method of altering the amount of work done, and thus affording a very convenient subject for test by the dynamometer; several interesting questions in heat are also opened, especially with reference to the heating of wires traversed by the current. In light not only does it bring the electric light within convenient reach for daily experiment, if desirable, and of photometric and spectroscopic examination, but by an incandescent wire it furnishes a constant source of light, which opens quite a new field in photometry. Again in electricity and magnetism the value to the student of such a current constantly in readiness can only be estimated by those who have had occasion to employ powerful batteries for similar purposes.

The want strongly urged in previous reports, of some form of motor in the laboratory, and so generally supplied in other

similar institutions, is still felt with ever increasing urgency, and seems to demand immediate action. The simplest solution seems to be to keep one of the engines, now in the building, constantly running and letting the escape steam pass again into the circulation. The loss of heat would then be very small, being only that converted into work, and that lost by conduction. A countershaft should be run the whole length of the building, and the various departments could thus have power constantly available. Running a second countershaft across the physical laboratory, power could be carried by cords to any part of the room. If this was done, many instruments like the Holtz machine and stroboscope could be run continually and regularly, while several important experiments, such as the measurement of work and power would be easily available to the student.

Some problems in Astronomy have so important a bearing on affairs of every-day life, that every well educated man should be able to solve them. For instance, the determination of the latitude and longitude, of the time, and the direction of the meridian. It is therefore proposed to introduce some experiments of this kind into the course of Physics and to let the students determine these quantities by the sextant and transit.

During the past autumn the students in physics were taken to the works of the Howard Watch and Clock Co. at the invitation of Mr. J. Hamblet, and to the rooms of Welch and Andres Magneto-Electric Telegraph Co. at the invitation of Mr. Andres. Both excursions proved both interesting and instructive, and it is hoped that many similar excursions may be carried out when the weather becomes warmer. Several problems have been assigned to the students in designing apparatus, and this is considered an important feature of the examinations. The demand for teachers of Physics would seem to justify the increasing number of students who are preparing themselves to fill such positions.

All of which is respectfully submitted.

EDWARD C. PICKERING,

Thayer Professor of Physics.

DEPARTMENT OF ENGLISH AND HISTORY.

President Runkle:

During the past and present years I have continued my efforts to bring my work within a manageable compass, and to give my instruction the form that would best meet the actual wants of my students. As the experience of each new year defines more clearly the distinctive character of our School, it becomes easier to determine the limits of each department. We are not a University, and cannot undertake the teaching of general subjects on a university scale. Our limited resources forbid the attempt to occupy a wider field than that which strictly belongs to us, namely, the sound training of young men destined for technical professions or for active business life. For the present, moreover, as I have before had occasion to point out, the imperfect preparation of our pupils compels us to keep the element of general study within even narrower limits than fairly belong to it, in order to secure, without detriment to the student's health, the amount of attention to technical study which is absolutely necessary to justify us in conferring our scientific degrees. While the standard of preparation for our school is undoubtedly rising, no sudden change can be effected through the influence of rigorous entrance examinations. We are in the midst of a slow-moving revolution in Education which will, sooner or later, make elementary English and scientific teaching what it should be; but for us to set our standard of admission much above the present teaching-capacity of the schools is either to put a premium upon

cramming or to deprive ourselves of students. Any industrious young man of sixteen or seventeen, of good capacity, and with such an amount of mathematical knowledge as will enable him to master our scientific course, and such a training in English studies as the schools are competent to afford, has a good right to claim access to the opportunity our school furnishes to qualify himself for a calling which requires technical preparation, without being held to the necessity of conforming to all the requisitions of an ideal scheme of Education, which it is impossible at present to realize.

Our scheme of *general* instruction must therefore be limited for the present, both by the limited attainments of the pupils, and by the very limited amount of time at their disposal after deducting that required by their professional studies. An attempt was made last year to remedy the difficulty of overwork by reducing the amount of time to be devoted to each separate study, while the original multiplicity of obligatory studies was retained. Experience soon showed that, though the evil of overwork was perhaps diminished, yet the reduction in the time assigned to many of the non-professional studies was so great as to leave it an open question whether the result produced in them was worth having. Compulsory attendance in non-professional work on the part of students already overtasked with professional study answers but little purpose, even when the will of the student is ever so good to profit by the instruction. It is far better, both for health and mental discipline, that the number of subjects should be diminished, and thus a reasonable amount of attention secured to those that remain. To make the English and historical instruction more efficient, I have therefore proposed—and the proposal has been adopted—that for regular students an option shall be given between the English and History and certain other general studies, and that the student shall be held to an examination only in such general study, or studies, as he chooses, liberty of voluntary attendance on the other general courses being at the same time granted to all students who have the inclination and can

find the time. Thus the abler and better prepared students may avail themselves of the opportunity to pursue a wider range of general studies, while the slower and worse prepared, by being relieved from compulsory attendance on so many non-professional lessons, will gain sorely-needed time for their strictly professional work. The instruction in general subjects will also gain the advantage of being relieved of a dead-weight of overburdened or unwilling attendants. The arrangement need not be considered as more than temporary. As the quality of the preparation brought up to us by candidates for admission improves, a larger element of general study may again be required of professional students.

This change of arrangements will not preclude the attendance of any student on the literary and historical lectures who has time enough for that, but not time enough for more. And I think that in literary and historical instruction mere lectures may be made of great value in organizing the student's miscellaneous knowledge, and giving system and direction to his miscellaneous reading. But attendance on them should be purely voluntary, and no farther requisition should be made in the way of examination than, perhaps, the handing in of a brief set of notes at the close of the course. It is absurd to expect from them the same results as from regular and systematic study. On the other hand, as the change is likely to give me a smaller body of students who will have time for work, I desire to state briefly my view as to the proper nature of that work. The question becomes more important, in consequence of the increasing number of students in the department of Science and Literature, who, not being candidates for either of the technical degrees, are expected to devote a larger share of their time to general studies.

It is obviously impossible for a single instructor to embrace in his instruction the whole of fields so wide as those of Literature and History. The mere reading of manuals and compends is *not* the study of Literature and History, but a bad and barren way of studying Biography and Chronology. Literature is

really studied where authors are really read, and if History can be taught at all, it can only be by some method which will teach the student not so much History as how to read History. For a teacher whose time is limited that object can best be accomplished by selecting some definite period, and arranging a system of reading and study on the part of his pupils, which shall bear some resemblance to the system of physical research and experiment pursued in the laboratories below. A library is the working-laboratory of the student of Literature and History, and the chief aim of the instructor should be to teach the art of handling and using books. So far as the object of making the student into a writer is aimed at, that cannot be done by setting him merely to the study of rules in the rhetorics but by turning him into the literary laboratory, there, in the closest connection with all his study of the writing of others, to practise writing himself. And where, as in the present case, the instruction in Rhetoric, Literature and History falls to the charge of a single teacher, it is obviously better to combine these subjects together as closely as possible rather than to separate them widely from one another by too careful attention to formal divisions.

The question as to what portion of History and Literature is best suited to be the subject of research and investigation by students in such a school as ours, can hardly be open to doubt. However desirable, as a matter of general culture, it may be for the man of business to be familiar with the whole record of the past, it is *essential* that he should understand the world he is to live in, and security had better be taken in school that he study that. I would therefore begin my course of instruction with the study of the present condition of things, and thereby supplement, as far as possible, our students' insufficient knowledge of civil and political geography. And it seems to me eminently suitable in such a school as ours, that special attention should be given to the statistics of Commerce and Industry, and to the history of those Arts and Sciences whose principles are the subject of study in other departments of the school.

The study of the present political, social and economical condition of the nations would naturally lead back to that of the events of the immediate past out of which that condition has arisen. The period of history beginning with the middle of the last century, includes several series of events which are specially adapted to be the subjects of extended investigation by students like ours. On the economical and industrial side it includes the whole story of those remarkable labour-saving inventions and of the application to them, as well as to locomotion, of the motive power of steam on which has arisen the vast fabric of modern commerce and industry, as well as the history of the wonderful growth and expansion of modern physical science in all its departments, while on the political side it embraces the story of our revolt from the mother country and the building-up of the republican institutions under which we live, as well as the outbreak of that great European revolution which followed, and a knowledge of the early stages of which is so essential to a right understanding of the present political condition of Europe. And further, this period includes the advent of a new era in literature in the appearance of that generation of writers who immediately preceded our own.

If I am right in the principle that the best method of studying literature is to read books, and the best method of teaching History is not to waste time on wide surveys and barren generalizations, but, by confining the student's attention to the detailed study of a definite period, to teach him how to investigate for himself, no period could be better suited to such a purpose than the one I have described. There is also this great advantage in teaching modern History and Literature, that while, to excite interest in the remote past, time, leisure and the cultivation of a special taste are required, no difficulty is found in interesting young men who are about entering upon the duties of active life either in the serious interests of the present or in the events of the immediate past.

But the study of History, if it is to be productive of any practical results, must be accompanied by, or must lead up to

the study of Political Science on the one hand, and of Economic Science on the other. The lectures on History are followed by a course on Law and Government in the form of commentaries on the U. S. Constitution, and a course on Political Economy accompanying the reading of a manual. These, for students in Science and Literature and for all regular students who enter this course for work, are accompanied by the collateral reading and writing described above.

As it is obviously useless as well as impossible to frame distinct courses for different sets of pupils, it will be seen that in my instruction I have to keep in view three sets of students; 1st, the regular students who can only attend lectures without work; 2d, regular students who elect to do work in connexion with my lectures; and 3d, "Science and Literature" students who have time for a larger amount of work. To meet the wants of the last, I organize small special classes, meeting in my library for supplementary reading and study. This has proved so interesting both to teacher and pupils that I propose to increase their number as far as time allows, and I see no reason why, under proper restrictions, volunteers from the regular classes and special students from other departments should not be admitted to them, without regard to the years in which they are classed.

Specimens of written work are herewith presented; among them elaborate papers on France and Russia by Messrs. R. C. Ware and S. H. Wilder, graduates in the department of Science and Literature, and one on British India by Mr. F. C. Bowditch, a special student in the department.

I have to report a uniformly excellent spirit in my department. I have never lacked interested and attentive hearers, and the conduct of the students in lecture-room and reading-room has been unexceptionable.

All which is respectfully submitted,

W. P. ATKINSON.

DEPARTMENT OF MATHEMATICS.

To the President: —

The instruction in this department now conforms to the new arrangement of studies contained in the catalogue. In consequence of this change, what was formerly a three years' course in mathematics is now concentrated within two years and two months. The number of exercises in the entire course remains unchanged, but instead of the former unequal distribution, there is now a uniform number of three exercises per week throughout the course. By thus completing his mathematical studies earlier in the course, the student is less embarrassed in those departments where this knowledge is applied.

Even more might be accomplished in this direction, if our students entered better prepared. Fully half of the First Year is now occupied in a review of branches which are among the requirements for admission. A higher standard of mathematical instruction in our preparatory schools will alone enable us to dispense with this review. A marked improvement in this respect is already apparent in some of the schools located near us, and if all our students before admission had the advantage of equally thorough instruction in mathematics, the course in this department would be materially strengthened. But when we take into account the character of the average instruction in mathematics in the high schools, where the majority of our students receive their preparation, it is evident that we cannot, at present, assume that thorough knowledge of algebra and geometry which will allow us to entirely omit these branches from our course. It is hoped, however, that at no distant day we shall attain this very desirable object, and that our students will complete their course in pure mathematics at the end of the second year.

GEO. A. OSBORN,

Prof. of Mathematics.

ABSTRACTS OF THESES PRESENTED BY GRADUATES OF 1873-4.

The following abstracts of the theses presented have been furnished either by the departments, or by the authors.

DEPARTMENT OF CIVIL ENGINEERING.

The students in Civil Engineering, of the class of 1874, were required to present as theses, designs for a single track railroad bridge, 192 feet in length. They were divided alphabetically into five parties of three each, and a different form of truss assigned to each party.

Of the fifteen students in the class, two were not candidates for a degree, two did not succeed in passing the examinations, and one has failed to hand in a thesis. The ten remaining, being those recommended for graduation, presented theses as follows:—

Herbert Barrows, a Post Truss; Wm. T. Blunt, a Post Truss; George E. Doane, a Double Warren Truss; Joseph S. Emerson, a Linville Truss; Elliot Holbrook, a Linnville Truss; Aechirau Hongma, a Warren Truss; Charles P. Howard, a Warren Truss; Herbert B. Perkins, a Murphy Whipple Truss; Edward S. Shaw, a Murphy Whipple Truss; Arthur W. Sweetser, A Murphy Whipple Truss.

The general treatment of the subject of these theses was necessarily nearly the same in all. A description of the particular truss is given, and its peculiarities pointed out. Next comes a discussion of the method of finding the shearing forces

and bending moments acting at different sections of the bridge, followed by a determination of the stresses upon the upper and lower chords, the struts, the main ties, the counter ties, and the connecting pins. The size that these members must have in order to sustain safely the stress upon them is then computed. The floor beams are next considered and the size fixed. The horizontal strain at top and bottom is also determined. Lastly, the weight of each member of the bridge is calculated, and the total weight of the bridge ascertained.

The drawings accompanying each thesis are two in number, and give a view of the finished structure in plan, elevation and section, and on a larger scale a diagram of stresses and the necessary details.

DEPARTMENT OF MECHANICAL ENGINEERING.

COTTON MANUFACTURE AND THE RING FRAME. ABSTRACT BY THE AUTHOR, F. H. SILSBEE.

In this thesis I have endeavored to present, more or less fully, the following points.

1. A general description of the growth of cotton cultivation, since the improved facilities for manufacturing it, and the structure of the cotton fibre.

2. The history of the introduction and progress of the cotton manufacture, and the most important inventions of cotton machinery, from the first introduction of this industry into England in 1760, to its introduction into this country in 1787, when the first cotton factory was built at Beverly, Mass.

3. A general account of the process of the manufacture of cotton cloth from the raw material, together with a slight description of the various machines employed and the object of their use.

4. The special spinning machine known as the Ring Frame, which is now so universally adopted in this country, especially for spinning the warp. This subject I have entered into the most fully, giving

(a) A brief history of the invention of the Ring Frame, which is due to John Thorp, of Providence.

(b) A general description of the frame, illustrated by a drawing; and also a detail description of the mechanism by which the traverse motion is obtained.

(c) An account of some of the most important styles of spindles and rings.

(d) Tables showing the power required to drive the various spindles, and also the power required to drive the frames under different conditions of banding.

(e) A table showing the strength of the Throstle, Ring, and Mule yarns.

(f) A summation of the merits and defects in the Ring Frame, as compared with the other spinning machines.

(g) An examination of the relative motion of the traveller and spindle, which shows that the traveller loses one revolution each time the yarn is wrapped once around the bobbin.

(h) A consideration of the matter of real and apparent twist, and the rules ordinarily adopted for calculating the same.

(i) A calculation of the irregularity in the twist, which arises necessarily from the manner in which the yarn is unwound from the bobbin, which shows that this irregularity is very s

(j) ... examination of the effect on the evenness of the yarn which the traverse motion causes; from which it appears that this motion produces no error in the twist.

(k) A calculation of the comparative work of friction of the ordinary or heavy spindle, weighing 11 ounces, and the Sawyer Spindle weighing 3¼ ounces; from which it is shown that about 86 per cent. of the difference of power required to drive the two frames is due to the friction arising from the weight of the spindle and empty bobbin, and diameter of step, the rest of the difference being probably used up in overcoming the friction caused by the tightness of the bands.

(l) A calculation of the speed of the traveller through

space, which is found to be at the rate of 30 miles per hour, when the spindles make 6,000 revolutions per minute.

THE CORLISS STEAM ENGINE. ABSTRACT BY THE AUTHOR, FRANK H. POND.

The earlier steam engines may be considered as steam-pumps, and that of Newcomen the connecting link between the steam-pump and the modern engine. Newcomen's engines, improved in various ways by Brindley, Smeaton, and other engineers, continued in use during the greater part of the last century; but it was in effect the same until the days of Watt, the result of whose labors has been a harvest of wealth, prosperity, and ingenuity, without a parallel in the history of the world.

I considered my subject in three parts.

Part First. The Efficiency of Heat Engines in general.

Part Second. The Efficiency of the fluid in Steam Engines. I deduced the formulæ for finding the area of the Indicator diagram, assuming a theoretical diagram as being the most simple from which to deduce them. This theoretical diagram is constructed upon four suppositions.

1. That the steam, when it enters the cylinder, presses upon the piston with the elasticity existing in the boiler.

2. That this pressure continues uniform, as long as the steam valve remains open.

3. That after the steam valve is closed, the pressure diminishes inversely as the volume of steam increases by expanding, according to Mariotte's law.

4. That the exhaust port is opened at the instant the piston reaches the end of its stroke, and remains open during the entire return stroke. Now this very seldom happens, as is shown by experience. The causes which affect the power of the engine, as well as the figure of the diagram, are wire-drawing at cut-off, clearance, compression, or cushioning, release, conduction of heat, and liquid water in the cylinder.

I then considered the effect of back pressure; the thermodynamic functions, and adiabatic curve, for mixed water and steam; the approximate formula for adiabatic curve; the liquefaction of steam working expansively; and the efficiency of steam in a non-conducting cylinder, of which the Corliss engine is a good example.

Part Third. The efficiency of steam in the Corliss engine. As Watt, in the last century, found the steam engine an imperfect and wasteful arrangement for utilizing only a small portion of the energy of the steam supplied to it, and by the invention of a separate condenser, and by his method of making the engine double acting, made it really a steam engine, so in this country the credit belongs to George H. Corliss, of Providence, R. I., for improvements by which, in the engine known under his name, simplicity of construction, together with perfection in economy of working have been secured. The improvements which Mr. Corliss has made in the mechanism of the steam engine, have been recognized by the American Academy of Arts and Sciences, and publicly acknowledged by this body in presenting him with the Rumford Medals, in January, 1870. I will give only one short extract from the address made upon the occasion by Dr. Asa Gray, President of the Academy, although in my thesis I have quoted at some length from it, as he gave a very fine description of the engine. After noticing the economy of fuel which the Corliss engine makes possible, compared with the older forms, Dr. Gray continues, "It is a great thing to say, but I may not withhold the statement, that, in the opinion of those who have officially investigated the matter, no one invention since Watts' time, has so enhanced the efficiency of the steam engine, as this for which the Rumford Medals are now presented."

The Corliss engine, from which I have taken my data in the following calculations, is a one hundred horse-power engine, built by the Corliss Steam Engine Co., Providence, R. I. The engine has been running about six months, in the largest printing house in the country, Messrs. Rand, Avery &

Co., 117 Franklin Street, Boston, Mass. The diameter of the cylinder is 18 inches, length of stroke 4 feet; when running with 60 lbs. of steam by the gauge, the engine makes 55 revolutions per minute. I took indicator diagrams from the engine April 18, 19, and 20 (1874). Diagrams will be found with the thesis, which were taken on each day, showing the manner in which we found the valves set, and as we left them. On April 19, we ran only the shafting, and found it took 20,082 horse-power. They were also running very light on April 20, the diagrams show 51.535 horse-power, or about half the capacity of the engine.

The following table shows the different ratios of expansion:

Rankine's correct (?) method	$r = 3.901$
" approximate "	$r = 4.369$
From indicator card, calculating the clearance .	$r = 5.61$
" " " measuring clearance with water	$r = 5.17$

Energy per cubic foot of steam admitted, 9014.986 foot-pounds.

Mean effective pressure, or energy per cubic foot swept through by piston, 12 lbs. per square inch, when $r = 5.17$.

Heat expended per cubic foot of steam admitted, 130305.5 foot-pounds.

Heat expended per cubic foot swept through by piston, or pressure equivalent to heat expended, 175 lbs. per square inch.

Net feed water per cubic foot sweot through by piston, .028 cubic feet.

Efficiency of the steam nearly 7 per cent. (.069)

THE SWAIN TURBINE. ABSTRACT BY THE AUTHOR, GEORGE H. BARRUS.

The Swain Turbine is what is known as a combined parallel and inward flow turbine. As the name of the class to which it belongs implies, it combines the forms given to parts of two dif-

ferent turbines, into a single one of the same size. The openings into the wheel embrace the upper part of its periphery, the remaining part of the depth being closed by a band. The orifices of discharge lie at the bottom and the inside, extending from the under side of the crown to the lower edge of the band. The direction of motion of the particles of water in passing through the buckets varies from a horizontal to a vertical direction, depending upon their positions on entering. The vertical components of these motions act in the same manner as the water in a parallel flow turbine, while the horizontal components act like the water in a real inward flow turbine. The condition of maximum flow through the wheel is satisfied by making the area of the gate openings equal to that of the orifices of discharge.

This subject is considered under five heads. The "Description of the Swain Wheel" consists mainly of the explanation of a sectional elevation of the wheel as it sets in quarter-turn.

Under "Construction" reference is made to some of the rules used in proportioning the principal parts, the method of laying out the bucket curves, and the process of casting the wheel. A few improvements are explained which were devised by Mr. A. K. Mansfield.

The third division is headed "Theory," and contains an explanation of the action of the water as it passes through the wheel, showing the deviation which it undergoes in encountering the curved bucket. The wheel is first considered as an actual inward flow turbine, and the formulæ derived are afterward changed by introducing the mean horizontal component, before referred to, making them applicable to the real case. In the next place, the equivalent parallel flow turbine is investigated with results of a similar character. In both, the principal object in view is to obtain the velocity of the water leaving the wheel, from which the efficiency, neglecting prejudicial resistance, is easily deduced. The formulæ serve also to show the proper values of the angles, guides, and bucket curves within certain limits.

Under "Method of Testing" a general description is given of the process of testing a turbine by the use of the dynamometer; and the method of computing the efficiency from the results of such a test. The last topic embraces a comparison of the Swain wheel with other turbines in use at the present time. With economy as the basis of comparison, two points are made which should be borne in mind in an examination for relative merit—efficiency and power. It is desirable that a turbine should possess both these qualities in as large a degree as possible.

The different methods of regulating the supply of water to the wheel are noticed and their effects upon the efficiency at part gate compared. A short table containing the efficiencies and powers of a few prominent turbines shows how these remarks apply.

DYNAMOMETERS. ABSTRACT BY THE AUTHOR, WILLIS H. MYRICK.

Whatever causes, or tends to cause, increased or decreased motion in a body is a force. The continuous action of a force through space is work, the amount of which may be expressed by the product of the force, and the space passed over by that force. Power is the rate of work, or the work performed in a unit of time.

The various uses of the dynamometer are to determine the force exerted, the work performed, or the power expended, wherever motion takes place or tends to take place. Of those kinds which have for their object the determination of force alone, the most prominent were invented by Graham, Desaguliers, Leroy and Renier. Graham's instrument as well as Desagulier's were modifications of the common steelyard, while Leroy's was similar to the spring balance. Renier's consisted of an elliptical spring very much like a carriage spring having a scale and pointer so attached that it showed the force applied.

As most of the dynamometers for measuring work can be used for measuring power, and *vice versa*, the different varieties

will be mentioned together under the heads of Traction, Transmission, or Absorption Dynamometers. Of the Traction form, Morin's is the only one which needs describing. It consists of two parallel rectangular springs, connected at their extremities, whose deflection taken with the distance passed over by the carriage determines the work.

A Transmission Dynamometer consists essentially of two pulleys, or shafts, one driving and the other driven, these being connected by springs, levers, or gears, in such a manner that they use up an amount of force equal to that which is necessary, at any instant, to produce the required motion, in the machine to be tested. The compression of the springs, or the amount of weight raised with the space and time, give the means of determining the power, or work. The connection between the driving and driven pulleys or shafts, varies in the different machines. In Morin's rotary dynamometer, it consists of a flexible rectangular bar, one end of which is fixed to the shaft the other to the driving pulley. A pencil is made to record the force on a moving strip of paper.

Eive's is a dynamometer with two radial springs projecting from the hub of one of the pulleys, whose extremities press upon two pins on the circumference of the other. The motion of one pulley relatively to the other, pushes the end of a rod over a cam. The motion of the rod indicates the force. Mr. Taurines has a dynamometer where the ends of two arms on the shafts are connected by springs, whose flexure determines the force. S. P. Ruggles of this city has one consisting of a pulley connected to the shaft by means of a spiral spring which encircles it. A screw and thread within the hub moves a rod which connects with the recording apparatus. Mr. Hirn obtains the work done by means of the torsion of the shaft itself. Brown's connexion consists of three spur gears in line. The middle one is small, and is attached to the short arm of a steelyard. Bachelder's is of the same principle, except that the combination, commonly called compound gears, are used instead of the spurs. Mr. Neers connects the driving with the

driven shaft by means of two discs, one fixed on the inner end of each shaft. To that disc which is connected to the driven shaft, are attached two springs which oppose the motion of two chains that pass over two small wheels, on the circumference of that disc, and connect with the other disc. The motion of this second disc pulls the chains over the small wheels, while the springs opposing their motion cause the first disc to turn with it.

Emerson's transmission dynamometer consists of a combination of compound levers, connecting the driving pulley to the shaft of the driven. The force is measured by a weighted pendulum.

While examining the defects which are so detrimental to transmission dynamometers as a class, the springs which most of them use form one of the most serious, as well as one of the most common. These springs are not only affected by temperature and by age, but from the effects of centrifugal force are pulled and twisted as they revolve around the rotating shaft, thereby causing false indications. Unbalanced parts rotating around a shaft are also acted upon by centrifugal force.

Upon examining Brown's and Batchelder's machines, we find that these defects are overcome, but in their stead, we find a force in motion which is carried through revolving gears, at high speeds, causing imperfect indications.

In the dynamometers about to be described, every precaution has been taken to overcome these objections, and to obtain what seems to be a dynamometer with but few, if any defects, except those of friction, which it is impossible to get rid of entirely. The following is the description of a machine which has been designed. Two short hollow shafts are situated in line with their inner ends somewhat separated. Each carries a pulley which may serve as a driving or driven pulley, together with a bevel gear placed at its inner end. Between these bevel gears and opposite each other are situated two smaller bevel gears, forming a set of compound gears. Each small gear connects by means of a short hollow shaft with a spur gear, the spurs being near the centre of the machine, their planes paral-

lel to each other, and to those of the small bevels. Each spur gear works in a rack, one rack being on the top of one spur gear, while the other rack is at the bottom of its spur. Both racks are connected to a rod which runs lengthwise of the machine, and through the hollow shafts first spoken of, appearing at the outer end of one. The rod here terminates in a step, the step pressing against a small steel block, which by means of a rack on its under side connects with a spur gear, to which is fastened a weighted pendulum.

If for an instant the driving pulley remains still while the driven pulley revolves, the small bevel gears will turn, consequently the spur gears, which will force the rod against the block, causing the pendulum to be raised. The pendulum reacts through the different parts, as the springs react in the other machines. Calculations have been made of the sizes of the various parts, but space will not permit their being inserted here.

Of the Absorption Dynamometers, the Prony Brake consists of several pieces of wood, connected by chains, which surround a shaft or pulley, they being held against the shaft or pulley by these chains which are connected to the short arm of a steelyard, the long arm being weighted until the shaft runs uniformly.

Mr. Emerson has made an improvement on this, by encircling the pulley with a hollow iron or brass band instead of the wooden blocks, water being forced through the band to keep it cool.

DEPARTMENT OF ARCHITECTURE.

DESIGN FOR A COUNTRY RAILROAD STATION. ABSTRACT BY THE AUTHOR, W. B. DOWSE.

This design was a solution of the problem given out in the Architectural department for a railroad depot, situated in a country town and which was to be built over the track. In its construction, stone or brick, iron and wood were to be used and

it was to be so arranged that persons could pass from their carriage to the train, under cover. To meet these requirements a bridge was designed, formed of circular stone ribs, at regular distances from each other and having a solid backing up to forty-five degrees, the stone ribs being bound together by brick-work. Stone and brick were also used in the outside walls of the building itself, to a height of about four feet, and in the signal tower, to the height of the roof of the main building. Iron was employed in the corridors and stairways, forming the covered passage to the trains below. The rest of the building was to be of wood. Through the backing of the ribs of the arch runs an arched corridor, giving additional breadth of platform.

Simultaneous with the designing, approximate calculations of the strength and stability of the parts were made, but as the building was not to be large, and consequently the strains upon its parts small, as also those upon the bridge, it was found that to have any architectural beauty many of the dimensions would have to be larger than they were required to be for strength. After the design was finished the calculations were made again, showing the *necessary* size of the component parts.

The frame of the roof consists of four intersecting trapezoidal trusses. The strains on them are due to the weight of roof. They must also be able to support the roof when loaded with snow. It was found that to resist the compression in the upper beam of the trusses it must have a cross section of 23 square inches. The necessary dimensions of the other parts were also calculated. The strength of the cast iron columns supporting the iron corridor, to sustain the weight of roof when loaded with snow, being the greatest strain it would be subjected to, was calculated and the cross section necessary was only .133 square inch, too small to be cast, as the columns were hollow and served as gutters, the real cross section being 18.06 square inches. The stability of the signal tower to resist the wind was found to be ample, as the necessary cross-section of each of the four main timbers of the frame, in order to resist compres-

sion or extension, according to which side the wind acted on—was only 3.08 square inches, but being used for ornamental purposes also, they were much larger. The necessary cross-section of the braces was also found. The track ran through a cut making it necessary to construct walls, in this case surcharged, battering-faced retaining walls, on each side. The necessary thickness of the base of the wall was found to be 3.86 feet. Its stability of friction was also found and the necessary depth of foundation, disregarding frost, was 2.47 feet. Calculations were also made on the strength of the brickwork of the arch and also of the stone ribs.

DEPARTMENT OF CHEMISTRY.

A FEW INSTANCES, SHOWING THE POSSIBILITY OF APPLYING THE MICROSCOPE TO INORGANIC QUALITATIVE ANALYSIS.

ABSTRACT BY THE AUTHOR, FRANK W. VERY.

I. Introduction. *a.* Disadvantages of the method; 1. High magnifying powers are required; 2. It is not so delicate as the ordinary one. *b.* Advantages of the method; 1. A small amount of substance suffices for an analysis; 2. It is more rapid than the ordinary one; 3. One test often detects two or more elements.

II. General directions for performing the microchemical analysis, together with some remarks as to the kind of tests which should be chosen in forming a system. (*a*) Apparatus. (*b*) Tests, embracing 1. Precipitation by chemical reaction. The largest crystals are formed from moderately dilute solutions; 2. Precipitation by a less solvent liquid. The production of crystals by the agitation of supersaturated solutions is often useful; 3. Crystallization by evaporation. The crystals produced in this way vary more than the precipitated ones; 4. Electrical deposition of metals.

III. Special cases. Scheme for detecting lead, bismuth, copper and cadmium in presence of each other. Embracing, *a.* Precipitation as carbonates by sodic carbonates. *b.* Solution

in nitric acid; 1. Precipitation of basic nitrate of bismuth by water; 2. Precipitation of plumbic nitrate by alcohol. *c.* Solution in chlorhydric acid; 1. Precipitation of plumbic chloride from the hot solution; 2. Evaporation of the chlorides of copper, cadmium and bismuth; 3. Evaporation with potassic chloride for cadmium. *d.* Solution in acetic acid; 1. Precipitation or evaporation of cupric acetate.

Scheme for distinguishing barium, strontium and calcium in presence of each other. Embracing, *a.* Precipitation as carbonates. The ordinary method. *b.* Solution in chlorhydric acid; 1. Evaporation of the chlorides of barium, strontium and calcium; 2. Precipitation of basic chloride by alcohol, also occasional precipitation of chloride of strontium; 3. Precipitation of the oxalates of barium, strontium and calcium, by ammonic oxalate and also by oxalic acid.

DEPARTMENT OF MINING ENGINEERING.

EXPERIMENTS ON WINNAMUCK SILVER LEAD ORES, FROM BINGHAM CANON, UTAH. BY B. E. BREWSTER.

REPORT ON THE DRESSING AND METALLURGICAL TREATMENT OF AN ARGENTIFEROUS LEAD ORE, FROM GEORGETOWN, COLORADO. BY F. H. JACKSON.

For full summaries of these theses, see "Studies in the Mining and Metallurgical Laboratories," on page 88.

DEPARTMENT OF SCIENCE AND LITERATURE.

FRANCE. BY ROBT. C. WARE. ABSTRACT.

Exceptional position of France in European history; an examination attempted of her present resources and condition, and of her past history, in order to forecast her probable future; difficulty of the subject; list of authorities; situation of France; frontier and coast surface; water-shed and river system; geology; volcanic formations; extent of tertiary and alluvial deposits; poverty in mineral wealth; climate; rainfall; agriculture;

forests; statistical tables from M. Block; population and its movements; slowness of increase.

Periods of history; barbaric, feudal, monarchic, revolutionary; extended sketch of each period; France since the fall of Napoleon III.; administration of Thiers; payment of indemnity; nature of the present provisional republic; debt; revenue; cost of the war; paper currency; exports and imports; division of land; loss of power by the R. C. church; education; immense recuperative power and favorable prospects as compared with Spain.

RUSSIA. BY S. H. WILDER. ABSTRACT.

Early condition of Russia; growing importance since the Crimean war; extent and general physical characteristics of the empire; northern Russia; central and southern Russia; surface and climate; water communication; detailed account of the geology of Russia; agricultural productions; forests; cattle, horses, sheep, etc.; mineral products; statistics of manufactures; railways and internal communication; foreign commerce; ethnology of the Russian empire; character and divisions of the Sclavonic race; the Finns and Lapps; early history; career of Peter the Great; reign of Catherine II.; Nicholas and the Crimean war; reforms under Alexander; emancipation of the serfs; Russian communism; the Russian church; the army; literature; list of thirty-six authorities consulted or read.

REPORT OF THE DEPARTMENT OF MECHANICAL ENGINEERING.

President Runkle: —

Dear Sir: — Since my report to you, made one year ago, quite important changes have been made in the course of instruction in this department. Two principal causes have led to these changes. They are,

1. The entire reorganization of the courses of instruction carried on in the Institute.

2. The existence of the long desired Mechanical Engineering Laboratory.

The nature of the reorganization of the courses of instruction was made very clear in the catalogue published one year ago. The scheme has worked admirably in my department, and while the duties of instruction in the strictly professional work of the course have been much increased, it has been possible to give the students a much more practical, thorough, and extended course of professional study.

The nature and uses of our Laboratory will be explained somewhat in detail in the latter part of my report.

We have now five sub-courses of professional instruction: — Mathematical, practical, graphical, excursional, and experimental. The number of text books and professional papers made use of in the course of instruction has been much increased. The same subject is, when practicable, under consideration in each of the five sub-courses at the same time. Such subjects

are selected for the consideration of the students as seem most important to the head of the department.

The text books to be used, the excursions to be made, the proper drawing and laboratory exercises are then arranged for; the object in view always being to give the students the most correct and practically valuable view of the subject that the time will allow.

My last year's report gives an idea of the work done in each sub-course, except the experimental. But it also suggests an experimental laboratory.

During the early part of 1874, all schemes for fitting up the laboratory fell through; but a little later, Mr. Geo. B. Dixwell called to consult me concerning certain questions relating to the nature and behavior of steam in some of its applications. I found that he had carefully examined a very large number of the best recorded experiments which bore upon the questions concerning which he wished to be enlightened. As some of his questions could be most satisfactorily answered by appealing to direct experiment, I advised him to go to some engine builder and undertake in connection with him such a series of experiments as would give him the desired information.

I further expressed my regret that our laboratory was not in active operation, as in that case we should be able to answer his questions at the Institute. He corresponded with engine builders upon the subject, but after deliberation decided to have the experiments conducted at the Institute. He saw that this decision would increase the expenditure that he would necessarily be at for the purpose of gaining his information. He also saw that in case the experiments failed to result as he anticipated, his expenditure would not be wasted, for he would have aided in establishing a Mechanical Engineering Laboratory, whose value, if properly used in a course of instruction, could hardly be over-estimated. It would make students familiar with the properties of steam on such a scale that the results obtained would be of *direct* value in their future practice, and of *direct* interest to all users of steam power. It would give them facili-

ties for becoming skilful in the manipulation of instruments used by engineers in testing steam boilers, engines, and kindred apparatus. They could be made familiar with, and thus taught to avoid the *legerdemain* of these instruments, by means of which some men frauduently, and many men ignorantly or carelessly, deceive the public or themselves.

To meet the generous contributions of Mr. Dixwell, I have, with your approval, made suitable expenditures. Two horizontal, wrought iron, multi-tubular boilers, which were formerly used for heating purposes merely, have also been connected with our apparatus.

I would now respectfully invite your attention to detailed descriptions of some of the more important parts of our apparatus, saying, once for all, that most of these descriptions were written by Mechanical Engineering students as regular Institute exercises. They formed parts of reports of experiments conducted by the students. I have taken the liberty of revising or of making such abstracts as seemed best, from their reports, and of then making them a part of this paper.

The Hot-water Collector described in the "Spectrum," a paper published last year by the students, is a plain, horizontal cylinder, its inside length being 13 feet 10 inches, and its inside diameter being 3 feet. The cylindrical part of the shell is of wrought iron, $\frac{3}{8}$ of an inch thick. The ends of the shell are flat cast-iron plates, 1 inch thick. The capacity of the tank is 97.78 cubic feet. It receives the hot water which condenses in the steam heating apparatus, and retains it until it is needed again in the boilers. The hot water is carried from this collector to a *Blake Pump*, through a 2 inch pipe, connected with which is a small cold water pipe for cooling the water, if necessary, before it reaches the pump. From the pump a $1\frac{1}{2}$ inch pipe passes along the front of the boilers. From this pipe a 1 inch pipe leads into each boiler. A cold water pipe is also connected with the $1\frac{1}{2}$ inch pipe. Its water will run into either boiler under 40 pounds pressure without the aid of the pump.

A Giffard's Injector, made by Wm. Sellers & Co., of Philadelphia, also forms a part of our boiler-feeding apparatus.

The Steam Producing Boilers, also described in the "Spectrum," are virtually alike, and the description of one is virtually that of the other. Each is 12 feet long, 4 feet diameter, and has fifty tubes, each of which is 3 inches outside and $2\frac{3}{4}$ inches inside diameter. About one half of the cylindrical part of the shell, both tube sheets and the inside surfaces of the tubes come in contact with the heated gases. The total area of heating surface per boiler is 530.35 square feet. The total boiler room is 121.34 cubic feet.

The following table shows the proportions of steam, water, and boiler room under certain circumstances :—

Height of Water.	*Cubic Feet of*		*Percentage of boiler room occupied by*	
	Steam.	*Water.*	*Steam.*	*Water.*
Lower Gauge Cock . .	65.42	55.92	53.9	46.1
Middle " " . .	49.72	71.62	41.0	59.0
Upper " " . .	36.59	84.75	30.2	69.8

There are suitable safety valve gauges, etc., on each boiler. Both boilers are provided with Etna grates; the grate area of each is 16 square feet. Two inspectors of the Hartford Steam Boiler Inspection and Insurance Company have certified that they have carefully inspected these boilers, that they find them in good condition in every respect, and that they are well adapted to bear with safety a pressure of 80 pounds to the square inch. They were built by Allen and Endicott, of Cambridgeport, in 1866. Two wrought iron chimneys carry away the waste gases from the two boilers; their capacity to carry off smoke is about one-half what is needed, and the result is at once an insufficient supply of steam and a wasteful consumption of coal. I would respectfully recommend that a suitable chimney, or a mechanical blast, be provided in order to remedy the defect.

The Small Boiler, described by Thomas D. Plimpton, is of the upright, wrought iron, tubular class, 7 feet long, and 8 feet

in diameter; the distance between the tube sheets is 5 feet and there are 50 two-inch tubes. The tubes, and also 12 stays each $\frac{3}{4}$ of an inch in diameter, connect the tube sheets with each other. The water space below the lower tube sheet is an annular ring, measuring 2 inches in a radial direction. This space is more strongly stayed than is usual in boilers of this kind. The boiler is set in brick work with a space left around its upper part, extending downward not quite so low as the lower tube sheet. The hot gases pass through this space, after leaving the tubes on the way to the chimney. The furnace and combustion chamber are detached from the boiler, and the hot gases can be directed through the boiler to the chimney, in which case, they give up their heat to the contents of the boiler, or the whole or any desired part of these gases can, at any time, be made to pass to the chimney by a flue which avoids the boiler entirely. This boiler always superheats the steam more or less, more in proportion as the water level is lower. It is provided with two sets of gauge-cocks, one set near the top and the other set near the bottom of the boiler. Glass gauges run from near the top to near the bottom.

Instead of using this boiler as a steam producer, it may be used as a superheater, or again, as a steam drum or "mechanical separator" merely. When used as a superheater or steam drum, steam is introduced from the producing boilers by a pipe 2″ diameter which enters the small boiler at the top and passes down into it about $3\frac{1}{2}$ feet. A deflecting plate prevents the escaping steam from impinging upon the surface of the water in the superheater or drum, should any water be there. The exit pipe is at the top and on the opposite side from that at which the admission pipe enters. This boiler was tested by an hydrostatic pressure of 250 lbs. per sq. inch. Two inspectors have pronounced it safe with a steam pressure of 150 lbs. per sq. inch. This boiler was built in the best manner by Thomas Cunningham, of Charlestown.

The Cast Iron Superheater, described by Thomas D. Plimpton, is a cast iron box, 4 feet long, 2 feet wide, and 4 inches

thick. It has partitions extending crosswise alternately from one side nearly to the opposite, causing the steam to take a zig-zag course as it passes through, and bringing the moving steam in contact with all its parts. These partitions also serve for stays and practically increase the area of heating surface.

It lies flat over its furnace; the hot gases passing over the back end, return over the top and then pass into a flue. This flue conducts the waste gases, still quite hot, through the tubes of the small boiler, or directly into the chimney at pleasure. This Superheater was presented by Prof. John M. Ordway, of the Chemical Department.

The Steam Engine is a Harris-Corliss, and was built for us by Wm. A. Harris, of Providence, R. I., who says that it was built in his best manner.

The cylinder of the engine is about 8″ by 24″, the clearance about .036 of the piston displacement. It does not differ in its general style from the usual Corliss Engine pattern. It is regulated to make about 64 revolutions per minute, and when cutting off at half stroke, produces about 20 horse power, with 70 lbs. initial pressure in the cylinder. The governor furnished with the engine is of the ordinary "common pendulum" variety, and like all Corliss Engine governors, regulates the admission of steam by varying the point of cut-off. The ordinary throttle valve has been removed from the engine, and a Huntoon Governor put in its place. This governor is, as is well known, a throttle valve governor. It was presented to the Institute by E. P. Boardman & Co., of Lawrence, manufacturers of the governor, in answer to our request for their lowest price. We can at pleasure control the engine with either governor. When one governor is in use, the other is made entirely inoperative. A Peet Valve in the steam pipe is used as a throttle valve.

The Principal Parts of the Calorimeter described by Geo. H. Parrus, a graduate of the Mechanical Engineering Department, and my assistant in the laboratory, are *a Brass Coil or Surface Condenser*, which does not leak; *a Small Tank* beneath, in which to collect the water which condenses in or

passes through the calorimeter: *Scales*, for weighing; *Thermometers*, for ascertaining temperatures; *a large, closed, rectangular wooden Tank*, containing the brass coil, the water which absorbs the heat that passes through the walls of the coil, and *the pump* which circulates the water; and *an Expansion Tank.*

The exhaust pipe of the engine passes through the wall of the large tank near one end and about two and one-half feet above the floor of the tank, where it is permanently attached to a nearly horizontal tube three inches in diameter and four feet long which forms a part of the coil or condenser. Another 3-inch tube lies parallel to this, near the floor at the other end of the tank. These 3-inch tubes are joined by a row of 20 Z-shaped brass tubes, one inch in diameter and 21 feet long. The Z-shaped tubes run the length of the tank, three times, falling about ten inches in each length. All the joints of the Z-shaped tubes and of the nearly horizontal tubes which they connect, are so designed that no cavities are left to collect water which condenses. When it is desired to measure the quantity of heat which is contained in a given mass of steam or water, that steam or water after traversing the exhaust pipe enters this nearly horizontal tube. All of the tubes slant sufficiently to allow any water which may arrive at or condense in any part of the coil to fall readily into a five-eighths of an inch drip pipe, which leads from one end of the lower 3-inch pipe. The drip pipe passes through the bottom of the large tank into a small tank beneath. Between the two tanks the drip pipe contains two check valves and a Chapman valve. The former prevent the water from being pressed back into the coil by the atmospheric pressure when the steam ceases to enter it. Air gains admission to the coil through a vacuum valve in the exhaust pipe near the tank. Whenever water enough has run into the small tank, the Chapman valve can be closed at any time, preventing all water from passing out of the coil. The water in the small tank can be carefully weighed, drawn off, and the weight of the empty tank taken in a short time. The

efficiency of the condenser is not diminished enough through the backing up of the water confined in the coil to affect very much the back pressure of the engine. This coil was carefully tested for leakage by letting on the full head of Cochituate water, the pressure of which was in excess of 40 pounds per square inch. At first there was leakage through minute blow-holes in the cast brass connections, and at some of the junctures of the tubes; but these defects were remedied by the application of soft solder. The tubes themselves are of seamless drawn brass, and, except in one or two points, exhibited no tendency to leak.

The Small Tank is made of 2-inch plank, four and one-fourth feet long, thirteen inches deep and thirteen inches wide. It is provided with a floating cover. A sheet rubber diaphragm extends from the outside edges of this cover to the inside edges of the top of the tank. The cover and diaphragm prevent the formation of vapor in the small tank. Without them, the water in the tank would lose both weight and temperature through surface evaporation. The outlet of this tank is a 3-inch pipe opened and closed by a Chapman valve. Only fifty seconds are required for emptying this tank. A Huddleston thermometer indicates at any time the temperature of the water contained in the tank. The weight of that water is indicated from second to second by the four hundred pounds Fairbanks' Scales upon which it rests. The ringing of an electric bell indicates the rising of the scale beam. Horizontal pieces of rubber hose of sufficient length connect the tank with all pipes leading to or from it. As the level of the platform of the scales changes but slightly during the operation of weighing, the rubber hose is but slightly bent and the sensitiveness of the scales is not much diminished. The rubber hose also serves to intercept the conduction of heat to or from the tank. Air communication with the inside of the tank can be made when desired, by a small valve provided for the purpose.

The Large Tank is built of 2-inch plank, strongly bolted together. Its inside dimensions are, length seven feet two

inches, width four feet two inches, depth four feet two inches. It is connected with the Cochituate hydrant by a 2-inch pipe which is opened and closed by a Peet valve. A Huddleston thermometer for determining the initial temperature of the Cochituate water used in the calorimeter is screwed into this pipe. It is about twelve inches long, and is graduated from about thirty degrees Fahrenheit to about one hundred and twenty degrees Fahrenheit. The bulb of the thermometer is surrounded by the water in the pipe and is subjected to the pressure of the water. The thermometer is quite near the large tank. The effect of the pressure on the surface of the bulb is not worth considering.

The outlet of the tank is a 3-inch pipe which leads from the bottom of the tank to the waste pipe. This is opened and closed by a Chapman valve. The tank fills in thirty-three minutes and empties in fifteen minutes. The faucets at one end of the large tank, one at the top and one at the bottom, allow water to be drawn from the tank, and two Huddleston thermometers, similar to those in the Cochituate pipe, except that the graduation extends to two hundred and twelve degrees Fahrenheit, one at the top and one at the bottom of the tank, show the temperature of the tank water.

The large tank rests upon a pair of five ton Fairbanks' Scales. All pipes leading to or from the tank are connected by horizontal pieces of rubber hose so long that their direction does not change much during the operation of weighing. The scales are sufficiently delicate to indicate a change of one pound in the weight resting on the platform. The rubber connections are of service in checking very much the transfer of heat to or from the tank. That one which is in the exhaust pipe has a stout spiral spring of about the same outside diameter as the inside diameter of the connection within it and running nearly its whole length, but not touching the pipe at either end. The pitch of the spiral is about three and one-fourth of an inch, and it serves to prevent the rubber from collapsing, when the steam is shut off before the atmospheric pres-

sure opens the vacuum valve. A safety valve attached to the exhaust pipe would blow off if the pressure in the pipe should ever reach ten pounds per square inch. No pressure, then, at all approximating to the bursting pressure of the rubber hose can ever come upon it.

The temperature of the water in the top of the tank would be much in excess of that of the water at the bottom, were it not for the *Circulating Pump*. This draws the cold water from the bottom and discharges it at the top, thoroughly mixing it. The induction pipe, about three-fourths of an inch by four feet, in cross section, is situated between one end of the coil and the same end of the tank. It begins near the bottom of the tank and extends upward as far as the top of the coil where it is terminated by a clap valve, about four feet long, opening upward. Passing through the valve the water enters a chamber reaching in height to the top of the tank, and about one foot by four feet in the plan. Leading out of this chamber near the middle of its length, is a rectangular trough, about four feet long and nine inches square, in cross section, in which the pump piston reciprocates, and through which the water passes out of the pump.

The Piston Head is a block of wood surrounded by a flanging piece of rubber which fills the trough during the forward stroke but collapses during the backward stroke, thus serving the purpose of a valve. It is worked by a rod which projects through a stuffing-box in the side of the tank. When eight hundred pounds weight of steam per hour is condensed in the coil, it is easy to keep the temperature of the water at the bottom of the tank within one degree Fahrenheit, or less, of what it is at the top, by means of the circulating pump.

The Expansion Tank is two feet square in the plan, and two and one-half feet deep. It gives the water an opportunity to expand as it receives heat through the walls of the coil. Without it, the expansive force of the heating water would readily burst the closed tank. With it, the hydrostatic pressure can never reach two and one-half pounds per square inch. A

2-inch connecting pipe passes upward through the cover of the large tank, and through the bottom of the expansion tank. A floating cover and rubber diaphragm similar to those of the small tank serve here a similar purpose. A valve in the side of the expansion tank allows communication with the air while the large tank is emptying or filling. The large tank is known to be full when the cover of the expansion tank is seen to float.

The Standard Test Gauge attached to the small boiler, described by Thomas Hibbard.

This Bourdon Gauge was manufactured by the American Steam Gauge Company expressly for the Institute, and is of the largest size. We understand that they have put their best work into it, and took the greatest care in graduating it, in order to make it as nearly as possible a Standard Test Gauge. It is graduated to one hundred and forty pounds subdivided to half pounds. The Company's Mercurial Column was used in graduating the dial. Both the gauge and the column were subjected at the same time to hydrostatic pressure, until the column indicated the desired pressure, say one pound per square inch. The proper graduation marks were obtained in a similar manner.

The gauge is attached to the exit pipe of the small boiler by a U-tube, five feet deep, which is filled with water to its highest level. By this means the tube of the gauge is entirely cut off from the *heat* of the steam, while the water readily transmits the pressure on its exposed surface to the air confined in the gauge. The advantage of this is obvious, for it is a well known fact that a gauge exposed to heat reads very differently at different temperatures. In fact, a Bourdon Gauge, under some circumstances, makes a very good pyrometer.

The Pressure Gauge on the Eastern Producing Boiler was made by the same process and by the same makers as the Standard Test Gauge. It is not quite as large as the test guage, but it was made with equal care.

The Thermometers used in determining the temperature of the steam, described by James H. Head, are two in number

and were made for us by Mr. Huddleston of this city. They are substantially alike. Each is about twenty inches long, and gives readings at intervals of two degrees from two hundred degrees Fahrenheit, to a little less than six hundred degrees Fahrenheit. They were graduated at atmospheric pressure by comparison with a standard thermometer and by calibration, thus giving a great degree of accuracy in their divisions. During some experiments the bulbs are immersed directly in the steam whose temperature is to be measured. The metallic case of one of the thermometers is screwed into the steam pipe about ten inches from the pipe leading to the gauge, so causing the bulb to be in the pipe and entirely surrounded by steam. The pressure of the steam on the bulb causes an error of excess in the readings, very slight at low pressures but increasing as the temperature and pressure increase. During other experiments a cup containing mercury is screwed into the opening of the steam pipe referred to. The thermometric bulb being immersed in the mercury acquires its temperature, which under certain circumstances will not differ materially from that of the steam.

Two of Bulkley's Pyrometers have been provided for ascertaining the temperature of the superheated steam. One of these is inserted in the steam pipe, between the place where the superheated steam passes into this pipe and the engine.

Two Richards' Indicators have been made for the Institute by the American Steam Gauge Company. Their springs were coiled from wire which was at first a little too stout. They were then reduced as much as seemed necessary, being tested from time to time by the process now to be described.

An indicator with its spring, pencil and card all in position, was reversed, so that its piston rod pointed vertically downward. A scale pan was suspended from the piston rod and a base line drawn by the pencil of the indicator upon the card. A sealed weight was then placed on the scale pan, and a new line drawn upon the card. If the two lines thus drawn were too near to each other, the wire of the spring was reduced in

cross section by a suitable tool. The indicators have also been tested very carefully under a steam pressure. They prove to be excellent instruments. An interesting report of this test, or rather series of tests, has been made by James B. Stanwood and Wilfred Lewis, but properly this report would be given in another place.

Indicator cocks have been attached to both ends of the cylinder of the engine, to the steam pipe near its juncture with the steam chest, and to the exit pipe of the small boiler about midway between the U-tube of the standard gauge and the thermometer. Indicators can readily be attached at those places and the pressure observed.

The Apparatus for Driving the Indicator Cylinders, described by Frank T. Sargent.

Two pulleys are fastened by set screws to the same shaft. The diameter of one is twenty-four inches, equal to the stroke of the piston of the engine, the diameter of the other is equal to the length of the diagram to be drawn on the indicator card. Both are one-fourth of an inch face and have grooves for strong, inelastic cords. About five inches from the crank end of the cylinder, there is placed a grooved carrier pulley, four inches in diameter. The top of this carrier, the top of the 24-inch pulley and the centre of a stud in the cross-head are in the same horizontal line, parallel to the piston rod.

A strong cord is fastened to this stud, carried over the 24-inch pulley to which it is so fastened that it can not slip in the groove, then around the carrier and back to the stud to which it is again made fast. Ordinarily, the 24-inch pulley is driven directly by the engine during the return stroke, and by stiff, quick acting springs during the forward stroke.

If from any accidental cause the speed of the engine should suddenly increase so much that the springs could not reverse the apparatus with sufficient rapidity, the cord running around the carrier pulley would enable the engine itself to reverse the apparatus and prevent accident to it. At either end of the cylinder and directly below the cocks to which the indicators are

fastened during an experiment are two carriers, each four inches in diameter, and one-half inch face, with three grooves. These carriers are driven during the return stroke by a stout cord attached to the smaller of the pulleys on the shaft before mentioned. They are driven by a quick acting spring during the forward stroke. These carriers are readily attached to or disengaged from the paper cylinders of the indicators by short vertical cords having convenient hooks and rings. By means of this nicely constructed apparatus, which was made for the Institute by the Lowell Machine Shop, the paper cylinders of the indicators have a motion at all times proportional to that of the piston of the engine.

The Steam-Pipe, Valves, etc., were put in position by Walker, Pratt & Co., of Boston. A 3-inch pipe conveys steam from the producing boiler to the engine or to the small boiler as is preferred. A two and one-half inch wrought iron pipe, thoroughly jacketed with asbestos felting, carries steam from the small boiler to the engine, to the superheater, or to the exhaust pipe of the engine, as may be necessary.

A three and one-half inch exhaust pipe, also covered with asbestos felting, carries steam from the engine, the small boiler, or the superheater, to the calorimeter, the pipes used for heating the building or to the waste pipe.

No valves were used in these steam connections which were not carefully tested for leakage, under hydrostatic or steam pressure, by Mr. Barrus or myself.

Very great pains were taken to avoid leaky joints in the piping. If any joints proved leaky upon trial, the leaks were stopped by rust or red lead cement, or new joints were made.

The Brake for consuming the power produced by the engine, is of very simple construction. Blocks of whitewood press against the rim of the main pulley, surrounding or partially surrounding it, as circumstances require. Two long, strong chains encircle these blocks, to which they are firmly attached by wrought iron staples. A scale pan or weight box is suspended by those ends of the two chains from which the sur-

face of the pulley runs. The other ends of the two chains are fastened to a fixed support. By varying the weights in the weight box, the power consumed by the brake can be readily changed.

Adjoining the engine room and opening from it, is a large, convenient room, which has been fitted up for the use of the students while they are working up the results of experiments, or for similar purposes.

Numerous pieces of special apparatus have been provided by Mr. Dixwell, for special experiments, but it would be premature to describe them in this communication.

The ultimate object of our laboratory instruction and experiments is to make the students so familiar with the nature of steam, heat and work, that they will feel that steam and heat are their obedient servants, that they will neither dread thermodynamic power nor deal with it recklessly, nor give undue weight to the opinion of men who know no more about such things than themselves. It will give them increased confidence in the judgment of men whose greater experience in, and whose thorough study of, these things makes them competent advisers. They can also learn something about that most important of all questions connected with the use of steam or of machinery, what is practical economy?

Among the experiments of a general character, for which we are now prepared, may be mentioned those on the conversion of work into heat or of heat into work; on the capacity of different bodies for heat; on the change of bulk of solids, liquids and gases, under constant pressure, due to changes of temperature when it is attempted to keep the volume constant; on the relation between the temperature and pressure of saturated steam; on the total heats of superheated or saturated steam or of a mixture of steam and water; on the latent heat of fusion or of evaporation; on the transfer of heat, by radiation, conduction or convection, through different substances or through different thicknesses of a substance; on the cooling of gases by expansion; on the conductivity of fluids and solids; on the boiling and

melting points of different substances; on the condensation of steam; on resistance to boiling; on the comparison of quantities of heat; on the measurement of heat by evaporation; on the efficiency of heating or cooling surface. Most or all of these experiments might be conducted without much reference to the practical bearing of their results, but by judicious selection of the experiments and by carefully calling student's attention to their results, several of them might be conducted in one general experiment having for its object the solution of a practical problem. In this way we are able to solve some of the questions proposed to us by Mr. Dixwell, and other experiments of a practical nature.

Some of the practical problems which we can readily solve, relying upon the Chemical Department for assistance in the analysis of substances are; those on the efficiency and cost of operating pumps, feed water heaters, etc.; on the cost of production of steam in dollars, or in pounds of coal; on the percentage of combustible matter contained in the fuel; on the efficiency of furnace and boilers; on the waste of unburned fuel in the solid state; the waste of unburned fuel in the gaseous and smoky states; the loss of heat in the hot gas which escapes by the chimney; on the uneconomical effects of forcing fires; on the efficiency and evaporative power of boilers under various conditions of pressure or with different kinds of fuel, and the effects of bad draught upon the evaporative power; on the comparative value of different kinds of grate bars; on different methods of introducing the air necessary for combustion and dilution; on the comparative value of different styles of bafflers and bridge walls; on the most economical rate of combustion; on the comparative efficiency of firemen in charge of steam-boilers; on the comparative economy of detached furnace boilers; on the economy due to increased heating surface; on the evaporative power of boilers; on the loss of evaporative power due to bad draught; on the increase of evaporative power due to the direct action of the radiant heat of the furnace or to steam draughts; on the examination of boilers by hydrostatic

pressure or by internal and external surface examination; the examination of steam and water gauges, gauge cocks, low-water detectors, safety-valves and similar apparatus; on the obstruction to the flow of steam through pipes, produced by bends and valves, and by pipe friction; on the economy due to the covering of steam pipes with non-conducting substances; on the efficiency of steam heating apparatus; on the difference between the pressure in the boiler and the initial pressure in the cylinder; on the efficiency of the steam in the engine; on the rejected heat of the engine; on the useful work of the engine; its indicated power; its efficiency with various rates of lead, cut off, release or cushioning; its efficiency at different speeds; its efficiency under a varying load; and its comparative uniformity of speed, whether controlled by a variable cut off governor or by a throttle-valve govenor: its comparative efficiency with superheated or saturated steam, or a mixture of steam and water in a steam-engine, under varying circumstances of initial or back pressure; or when cutting off at different points of the stroke; adjustment of the eccentric and valves; on the adjustment of governors; on different kinds of piston packing; on cylinder and lubricating oils; on friction in the engine; on cylinder condensation.

Experiments already conducted on the economy of diminishing the leakage past imperfect steam-engine valves and piston packing have demonstrated the fact well known to experts, that the prevention of leakage is very important to users of steam-engines.

Other experiments of equal value intrinsically are those upon cylinder condensation, the economy of using steam at different grades of cut off, the use of superheated steam, the expansion of steam in the cylinder, and many others.

The object of some experiments would be to enable the students to become skillful in the manipulation of instruments used by engineers in testing steam boilers, engines and kindred apparatus. These experiments are so planned, that the defects resulting from the ignorance or carelessness of the experimenter,

will become very apparent to him when he comes to work up the results of the experiments.

The object of other experiments is to give the students experience in examining critically the instruments used in tests, making them familiar with their defects, enabling them to avoid some of the errors that inexperienced people are likely to make in their use, and to correct those other errors which of necessity exist in the best instruments.

Concerning the experiments on the critical examination of instruments used in tests, it ought to be said that most of the steam gauges, thermometers, and similar instruments that are to be found in the market are not intended by the manufacturers to be instruments of precision. Something which will tell what the steam pressure or the temperature is, in the rough, answers the purpose of a large majority of customers. These rough instruments being good enough for their purpose, they do not care to pay for more accurate, but at the same time, more expensive ones. But the makers of such apparatus manufacture a better class of instruments intended to be used by experts and others in various tests. These are much more expensive and are made with much greater precision. Engineers generally rely upon them for all ordinary purposes, and as often as they have reason to suspect that their accuracy has deteriorated, they are in the habit of sending them back to the makers to be readjusted.

But even the adjusted instruments are not sufficiently accurate to answer truthfully, nice scientific questions. Instruments suitable for such a purpose are very rarely wanted, could never be made profitably except upon order, and only then at very great expense by very careful men. Not many such instruments have ever been made, and when Regnault and other precise experimenters needed them, they were obliged to make them themselves. From the outset our laboratory was intended to be one in which practical experiments could be made in the ordinary way. Its most important use was believed to be to give young men skill in such kind of experimenting as would be of practical value. And while, as far as was possible, the

best apparatus to be had upon order in the American market was obtained, we have not supplied ourselves with that exceedingly precise apparatus which can not be bought.

The celebrated experiments by Regnault determined under very favorable circumstances, with instruments of extraordinary precision, the law which connects the pressure and temperature of saturated steam. As we can easily make saturated steam of any desired pressure, one instrument of precision, either of pressure or temperature, taken in conjunction with Regnault's law, would give us the means of examining critically each of our instruments for measuring pressure or temperature, and of forming a connected scale which would practically convert them into instruments of precision; for our apparatus is delicate and sensitive, and so far as we know now, indicates the same pressure or temperature whenever subjected to the same influences.

In the former part of this report the statement was made that our indicators had been tested very carefully. It was thought to be desirable to make a critical examination of the standard test gauge, the thermometers and the indicators, under the conditions of ordinary working. Accordingly, the three instruments were attached to the exit pipe of the small boiler, at points whose positions have been described in a former part of this paper. It will be remembered that the gauge was graduated to correspond with a mercurial column; that the thermometers were graduated by comparison with a standard thermometer and by calibration, and that the indicator springs were adjusted very nicely by means of sealed weights hung upon the piston rod. We had no special reason for doubting the accuracy of either of the instruments nor that of one more than that of another; and the examinations already made have satisfied us that they were, practically speaking, excellent instruments in excellent condition; but they had not been compared with one another, and had not been compared with a common standard. We were able to compare them with one another, and that we proceeded to do. After several preliminary experiments, it was decided on account of the rapidity with which the thermometer

showed changes of temperature to take the thermometer temporarily as a standard. By observing the pressures indicated by the gauge and the indicators, we should be able to judge of the accuracy of the instruments according as they corresponded with or deviated from Regnault's law. It was decided to make six experiments, three of which would compare both the gauge and the indicator numbered 562, and three others, which would compare both the gauge and the indicator numbered 567, with the thermometer assumed to be a standard. The indications of the gauge were observed by Mr. Thomas Hibbard, who made the following report:—

"Six experiments have been tried to test the gauge and compare it with Regnault's tables. In the first place, steam is blown through the small boiler which is used as a steam drum, in order to expel the air and heat up the apparatus. The valves are then closed; thus confining a certain quantity of steam in the drum, which rapidly condenses. The pressure is thus lowered below the atmospheric pressure, 14.7 pounds per square inch, and the temperature below 212° F. Everything is now ready for the experiment. Steam is admitted from the large boiler by opening the admission valve by degrees. The steam being throttled, the temperature and pressure in the drum rise slowly. The operator who reads the thermometer gives the word at every 9° F., commencing at 212° F. Just at those instants the pressure given by the gauge and indicator, is observed and recorded. The gauge was read to tenths of a pound, as nearly as could be judged by the eye. When the pressure in the drum rises so as to be nearly that in the boiler, the admission valve is opened to its widest extent. Then the steam pressure is allowed to rise gradually in the producing boiler, until it reaches about seventy-five pounds. The pressure in the drum, which is in free communication with the boiler, rises about the same. When the thermometer reads 320° F, corresponding to this greatest pressure, the admission valve is closed, thus shutting up the steam in the drum. Condensation now takes place, the temperature and pressure fall, and the readings are taken for

every 9°, beginning with 320° F, down to 212° F. To accelerate the condensation, the fire-doors and dampers of the drum were opened, thus causing a draught of cold air through the tubes. When the temperature falls to 212° F. and the pressure to about 0 pounds, the experiment is complete.

"In three of these experiments the barometer was read and the corresponding deduction or additions calculated for the height of the mercury column above or below 29.92 inches, or 14.7 pounds pressure. The mean readings of the gauge for each three experiments were ascertained, and the differences between them and Regnault's corresponding pressures determined. Now with the temperatures for abscissæ, i. e., distances measured horizontally, and these differences as ordinates, or vertical distances, two curves were constructed. The straight horizontal line represents Regnault's law of pressures and temperatures, while the constructed curves in the same manner show, upon the assumption that the thermometer is correct, the errors of the gauge. It was noticed that, when the gauge was tapped, it started ahead a little, not exceeding two-tenths of a pound, however, thus showing that there was some friction in the mechanism of the gauge. Most of the pressures registered by the gauge were within one pound of Regnault's pressures, while but few of them differed by two pounds. Most of the readings were less than Regnault's, seeming to show that either the gauge did not record as high pressures as it should, or that the thermometer read too high temperatures. The curves also indicate this, since they lie almost wholly below Regnault's line. There are many sources of error in such an experiment, but we hope by repeating them a number of times, and taking the mean reading, to get a table of corrections for the gauge."

The diagrams from indicator No. 562 were taken by Mr. J. B. Stanwood, an extract from whose report is as follows: —

"The test that was made on indicator No. 562 was to determine if the pressures indicated by the instrument corresponded to the pressures calculated by Regnault in his table of temperatures and pressures for saturated steam. These tables

were taken for our standard; they have an increase in the temperature column of 9°, that is, pressures are given corresponding to every 9° from 32° F., upwards. A Huddleston thermometer was used, together with the indicator, and both were placed on the steam pipe leading from the small boiler. In using the indicator, steam was kept in the cylinder until a few seconds before the line was to be drawn; it was then all shut off, and that which remained in the cylinder passed off into the air. Then steam was readmitted, and the line was taken just as the mercury passed the 9° mark. The reason for shutting off the steam and readmitting it, was in order to overcome any friction which might retain the piston in its place. At the beginning of the experiment steam was allowed to pass through the small boiler from one of the large boilers until all the air had been blown out and the boiler had been well heated up. Then the boiler was cut off from the external air, and from the large boiler, the steam that remained in it was allowed to condense until its temperature was about 210° F., then the steam was admitted slowly from the large boiler, and for each 9° passsd through by the mercury a line was taken by the indicator, showing the difference of the steam pressure from the atmospheric pressure; the first reading was taken at 212° F., and the last at 320° F. When the experiments first commenced, the pressure in the large boiler was about thirty pounds per square inch above the atmospheric pressure; as soon, however, as the pressure in the small boiler was the same, the pressure was allowed to increase in the large boiler. After the temperature was greater than 320° F., the small boiler was entirely shut off from everything, and the pressure then decreased by the condensation of the steam. Thus three experiments were made and six cards taken, three for ascending pressures and three for descending; from these cards the results of the experiments are obtained.

"After the experiments had been performed, two curves were constructed to show the variation of the indicator from the tables. One of these curves was for ascending pressure, the

other for descending. A horizontal line was taken to represent Regnault's curve of pressures and temperatures; the temperatures were measured off on this line as abscissas, while the difference between the table pressures and the observations were taken as ordinates. In order to obtain the two curves only from the six different observations, the mean observation for each temperature was taken for both ascending and descending pressures, and the differences between these and the tables were taken as ordinates. The curves were below Regnault's line, until they arrived at the temperature of about 248° F., and were then above Regnault's line, the ordinates steadily increasing between 248° and 320° F. If, now, instead of trying to make our instrument more accurate we construct a table taken from experiments, we can correct for errors and obtain better results than otherwise."

The diagrams from indicator No. 567, were made by Mr. Wilford Lewis, who says in a part of his report: — "In these experiments the indicators seemed to have an almost constant error of about eight-tenths of a pound below the pressure as given by Regnault's tables. This may be due partly to the pressure of the atmosphere being about 14.7 pounds, or to a constant error in the reading of the thermometer."

Without going so much into the details of the results of these experiments as to make them very tedious, it is enough to say that neither the indicators nor the gauge gave always the same pressure for a given temperature. Take, for instance, the pressure given by the gauge when the thermometer read 266° F., as the temperature was rising. The different readings of the gauge at that temperature were as follows: —

Experiment.	*No.* 1.	*No.* 2.	*No.* 3.		*No.* 4.	*No.* 5.	*No.* 6.
Gauge rising	24.25	24.4	24.1	Gauge rising	24.	23.5	24.8
" falling.	24.4	25.7	24.	" falling	23.9	24.	24.
Ind'r 562 rising	25.5	25.	24.6	Ind'r 567 rising	23.3	23.2	24.
" " falling	24.6	26.5	24.2	" " falling	24.1	24.2	23.9

The barometric pressure was noted in some of these experiments but not in others; but the discrepancies could not be ac-

counted for by changes in the atmospheric pressure. Some of the gauge readings differed as much as 2.2 from others, and as there must have been a reason for these differences, I concluded to plot the different experiments, and to ascertain, if possible, the causes which produced the discrepancies. They were plotted according to the system previously indicated; Regnault's law being represented by horizontal lines, horizontal distances representing degrees of temperature on a scale of ten to the inch, and vertical distances representing, on the assumption that the thermometer is correct, the error of the instrument on a scale of one-half pound to the inch.

All indications made while pressures were rising, were indicated by circles. All those made while pressures were falling, were indicated by diamonds. All made by indicator 562 were represented by black ink; all made by indicator 567, by blue ink; all made by the gauge by red ink. The first set of diagrams showed the errors in all the pressures observed with any one instrument on a sheet by itself. This set resembles a chaos of spots. The second set showed the comparative indications of all three instruments in any one experiment.

In the diagram of the first experiment, the gauge showed almost the same indications with rising as with falling pressures, but the indicator showed from one-quarter pound to one pound more pressure when rising than when falling.

In the diagram of the second experiment, the gauge at any temperature seemed to differ from the indicator about as much with rising as with falling pressure; but both the falling curves were crooked or warped in a remarkable manner.

The diagram of the third experiment resembled that of the first except that the falling curves had changed about equally the angle which they made with the rising curves. The diagrams of the fourth, fifth, and sixth experiments also showed that some cause or causes apparently affected both instruments at the same time.

A third set of diagrams was now made, showing the errors in all the rising pressures observed with any one instrument, on

separate diagrams from those exhibiting the errors in the falling pressures.

A careful comparison of these diagrams, with the recorded details of the experiments, led to the belief that one or more of six causes might have given rise to the discrepancies.

If the thermometer was slow to indicate changes of temperature; if the barometer changed considerably during the progress of an experiment; if saturated steam of a given pressure sometimes varied a little in temperature; if what we had supposed was steam had been a mixture of steam and air; if the steam which we had supposed was saturated had been superheated by any means, as by wire-drawing or by radiation of heat into it; if the indications had been incorrectly observed or recorded; these anomalies might have occurred. Some of these apparent causes could not be seriously entertained. The others were more likely to have acted, and it was determined to ascertain by further experiment whether the thermometer was dilatory; whether the steam was superheated; or whether the errors of observation need be very large.

The first new experiment was arranged on the supposition that the thermometer was dilatory. It was easy to make the indicated pressure vary about one and one-fourth pounds by changing the circumstances of the experiment.

A second new experiment was arranged to show still more clearly that the thermometer was dilatory. The gauge was taken as a standard and a slight current of steam was made to pass through the drum for three-quarters of an hour. During this time the pressure in the producing boilers was pretty constantly twenty-eight ponnds, and the pressure in the drum very precisely twenty-five pounds by the test gauge. The temperature of the steam as indicated by the thermometer with its bulk in steam was very constantly 269.25° F. This temperature is what would have been expected, had the pressure been about twenty-six pounds per square inch.

As there was no water in the drum, a relief valve was suddenly opened, reducing the pressure as quickly as possible to

one pound per square inch. Observations were then taken every five seconds. A slight current of steam passed constantly through the drum, while the pressure was maintained at one pound per square inch by throttling the admitted steam. The first temperature observed was 252° F. After about one minute, the temperature rose to 253.5°. This is the temperature of saturated steam of a pressure of about seventeen pounds per square inch, while the real pressure was only one pound. This dilatory behavior became exc ting. The readings taken every five seconds became monotonous. The students became hoarse with calling readings. After ten minutes the thermometer had fallen only to 240°; after thirty-eight minutes, to 221°; after forty-six minutes to 219.25°. To hasten the cooling still more, if possible, cold water was pumped into the drum. It did not cover the orifice through which the steam was entering. The temperature remained at 219.25° so long that our time and patience became exhausted. We then increased the pressure as rapidly as was considered safe, to 24.5 pounds per square inch, and the thermometer then read 268°. Throughout the remainder of the experiment, when the gauge indicated twenty-five pounds per square inch, the thermometer indicated 269°. We anticipated 269.25°, but as one-quarter on the scale was a small quantity, this difference was not suprising.

It was concluded from this experiment that the record of the thermometer was approximately true, but that the steam was superheated during the time that the gauge indicated one pound pressure. It was finally concluded that we should get the most reliable experiments by starting with steam at about atmospheric pressure in both boiler and drum, and gradually increasing the pressure at a very slow rate, comparing the indications of each of the instruments before mentioned with an accurate mercurial column, so arranged that its indications could be corrected for the temperature of the mercury in the column.

An extended series of experiments on cylinder condensation at different grades of cut off, with a pressure of seventy pounds

of steam in the boiler, has been partly concluded. The records of these experiments show not only the total heat of the steam which left the boiler, but also, approximately, the total heat in the steam at different points of the stroke, between the cut off and release, and, finally, the heat rejected by the engine and carried by the exhaust steam into the calorimeter. Each experiment with saturated steam at a given point of cut off, is supplemented by an experiment with superheated steam having the same initial pressure and cutting off at the same point. The results already arrived at are very interesting, and when the series is concluded I shall have valuable information to report to you. I am

Very respectfully yours,

CHANNING WHITAKER,

In charge of the Mechanical Engineering Department.

CORPORATION

OF THE

MASS. INSTITUTE OF TECHNOLOGY.

FOR THE YEAR 1874-75.

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JOHN D. RUNKLE.

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OF THE

SOCIETY OF ARTS

OF THE

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,

MARCH 1, 1875.

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* Prof. Daniel Treadwell, Cambridge, Mass.

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Bullard, W. S. . . "

Colby, Gardner . . "
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Gardner, John L. . "
Gookin, Samuel H. . "
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Greenleaf, R. C. . . "
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Kuhn, Geo. H. . . "

*Lawrence, James . "
Lee, Henry . . . "
Lee, John C. . . . "
Lee, Thomas . . "

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Little, James L.	Boston.
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McGregor, James	"
Mudge, E. R.	"
Nichols, Lyman	"
Norcross, Otis	"
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Richardson, J. B.	"
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Rogers, William B.	"
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Sayles, Mrs. Willard	"
*Sears David	"
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*Skinner, Francis	"
*Stetson, Joshua	"
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*Upton, George B.	"
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Wales, T. B.	"
Wales, Miss	"
*Whitney, Joseph	"

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Atkinson, Wm. P.	"
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Goddard, Nathaniel "
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Guild, Henry . . "

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Hall, Charles B. . . "
Hall, Thomas . . . "
Hamblet, James . . "
Haven, Franklin. . "
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Holmes, O. W. . . "
Homans, C. D. . . "
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Hyde, Henry D. . "

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Kendall, Edward . . "
Kneeland, Samuel . "

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Lanza, Gaetano . . "
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Lee, Francis L. . . "
Lee, Thomas J. . . "
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Lincoln, F. W. . . "
Little, James L., Jr. "
Little, John M. . . "
Lothrop, Sam'l K. . "
Lowe, N. M. . . . "
Lowell, John . . . "
Lyman, Theodore . Brookline.

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Markoe, G. F. H. . "
Marshall, H. N. F. . "
Mason, Robert M. . "
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McMurtrie, Horace . "
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Morse, John T. . . "
Morse, Samuel T. . "
Munroe, William . "

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Norton, Jacob . . Boston.

Ordway, John M. . W. Roxbury.

Page, Edward . . Boston.
Page, W. H. . . . "
Parsons, Wm. . . "
Paul, J. F. . . . . "
Peabody, O. W. . . "
Perry, O. H. . . . "
Philbrick, Edward S. "
Philbrick, John D. . "
Pickering, E. C. . . "
Pickering, H. W. . "
Pierce, S. S. . . . "
Plumer, Avery . . "
Pope, Edward E. . "
Prang, Louis . . . "
Pratt, George W. . "

Pratt, T. Willis . . Boston.
Putnam, J. P. . . "

Quincy, Edmund . Dedham.
Quincy, Josiah . . Boston.

Revere, Joseph W. . "
Rice, Alexander H. . "
Richards, R. H. . . "
Ritchie, E. S. . . . Brookline.
Robbins, James M. . Milton.
Robinson, J. R. . . Boston.
Rotch, Benj. S. . . "
Royce, H. A. . . . "
Ruggles, John . . "
Runkle, John D. . Brookline.
Russell, LeBaron . Boston.

Salisbury, D. Waldo "
Sawyer, Edward . Newton.
Sawyer, Timothy T. Charlestown.
Sears, Philip H. . . Boston.
Shedd, J. Herbert . "
Sherwin, Thos. . . Dedham.
Shimmin, Chas. F. . Boston.
Shurtleff, A. M. . . "
Sinclair, Alex. D. . "
Smith, Chauncy . . Cambridge.
Snow, S. T. . . . Boston.
Sprague, Chas. J. . "
Stackpole, G. W. . "
Stevens, Benj. F. . "
Storer, H. R. . . . "
Storer, Jacob J. . . "
Strater, Herman, Jr. . "
Stuart, Chas. F. . . "
Sturgis, John H. . "

Sullivan, Richard . Boston.

Thompson, Wm. H. "
Thornton, J. Wingate "
Tufts, John W. . . "
Tuxbury, Geo. W. . "

Upham, J. B. . . "
Urbino, S. R. . . . "

Walworth, J. J. . . "
Ware, Chas. E. . . "
Ware, Wm. R. . . "
Warren, Cyrus M. . Brookline.
Warren, Geo. W. . Boston.
Warren, Joseph H. . "
Warren, Sam'l D. . "
Waters, C. H. . . . Clinton.
Waterston, R. C. . Boston.
Watson, R. S. . . Milton.
Watson, Wm. . . Boston.
Weld, Stephen M. . "
Weston, David M. . "
Whipple, Edwin P. . "
Whitaker, Channing Lowell.
Whitman, Herbert T. Boston.
Whitmore, Wm. H. . "
Whiton, David . . "
Wilder, Marshall P. Dorchester.
Williams, H. W. . . Boston.
Winthrop, Robert C. "
Wood, John F. . . "
Wright, John H. . . "
Wyman, Morrill . . Cambridge.

Zalinski, E. L. . . Boston.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

PRESIDENT'S REPORT

FOR THE

Year ending Sept. 30, 1875.

BOSTON:
PRESS OF A. A. KINGMAN.
1876.

INSTITUTE BUILDING.

INSTITUTE BUILDING.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

PRESIDENT'S REPORT

FOR THE

Year ending Sept. 30, 1875.

BOSTON:
PRESS OF A. A. KINGMAN.
1876.

Extracts from Acts of the General Court of Massachusetts, in relation to the Massachusetts Institute of Technology.

Act of Incorporation. "William B. Rogers [and others named], their associates and successors, are hereby made a body corporate, by the name of the MASSACHUSETTS INSTITUTE OF TECHNOLOGY, for the purpose of instituting and maintaining a Society of Arts, a Museum of Arts, and a School of Industrial Science, and aiding generally, by suitable means, the advancement, development, and practical application of sciences in connection with arts, agriculture, manufactures, and commerce."

Chapter 183, *Acts and Resolves of* 1861.

Grant of Public Lands. "When the Massachusetts Institute of Technology shall have been duly organized, located, and established, ... there shall be appropriated and paid to its treasurer, each year, on the warrant of the Governor, for its endowment, support, and maintenance, one third part of the annual interest or income which may be received from the fund created under and by virtue of the 130th chapter of the Acts of the 37th Congress, at the second session thereof, approved July 2, 1862 [giving Public Lands to the States in aid of instruction in Agriculture, the Mechanic Arts, and Military Science and Tactics]. . . . . Said Institute of Technology, in addition to the objects set forth in its Act of Incorporation [as above quoted], shall provide for instruction in military tactics."

Chapter 186, *Acts and Resolves of* 1863.

Power to confer Degrees. "The Massachusetts Institute of Technology is hereby authorized and empowered to award and confer degrees appropriate to the several courses of study pursued in said Institution, on such conditions as are usually prescribed in universities and colleges in the United States, and according to such tests of proficiency as shall best promote the interests of sound education in this Commonwealth."

Chapter 247, *Acts and Resolves of* 1865.

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PRESIDENT'S REPORT.

To the Corporation of the Institute:—

Your attention is respectfully invited to the following reports and matters relating to the various departments of the Institute for the current year, the tenth since the establishment of the School.

The only changes in the corps of Instruction during the year have been the resignations of S. Edward Warren, C. E., Professor of Descriptive Geometry, Stereotomy and Drawing, and Edward K. Clark, S. B., Instructor in Mechanical Drawing.

Instructor William E. Hoyt has been given charge of the Stereotomy, Instructor Wells of the Descriptive Geometry, and Assistants Francis T. Sargent and J. Austin Knapp, of the Mechanical Drawing in the department of Mechanical Engineering.

Attendance. The whole number of students in attendance for the year 1874–75, was 288; a decrease of 22 from the preceding year. Of the 73 applicants for admission to the first year, at both the June and September examinations, 29 passed without conditions at an average of 73 per cent.; 26 passed with conditions at an average of 51 per cent.; and 18 failed to pass. Based on the mathematics alone these averages were 81 and 60 per cent. Of those admitted 15 did not join the class.

These reductions left a class of 40 new men, and one repeating, 36 of whom were regular students, and 5 special. It will be noticed that 25 per cent. of the applicants failed to pass, and that over 25 per cent. of those who passed did not join the class, mainly on account of the continued hard times, as was afterwards ascertained. Sixteen new students entered the second year, 8 without, and 8 with conditions. The average age of the class entering the first year was 17 years and 10 months.

Preparation for Admission. The suggestions made on pp. 210–215 are respectfully submitted to teachers by the Faculty, in order to make the work of preparation as definite as possible. The poorest preparation has usually been upon what are properly the grammar school studies. It is not overlooked that public policy usually demands that the High School must accept such preparation as the Grammar Schools can furnish, and should not therefore be held wholly responsible for these studies. Still it is hoped that the High Schools may be able to remedy the defect, in part, by requiring a careful revision during the early part of their course of such portions of the subjects as have been pointed out. Moreover, it cannot be denied that a large proportion of the High Schools continue to maintain classical departments for the purpose of fitting students for admission to College at a cost altogether disproportionate to the end gained. It would be far more economical for each town to support the few students who enter College from its High School, at a good classical school, and thus save the time and energies of the best teachers for other subjects of growing importance, as the modern languages, mechanical and free-hand drawing, chemistry and physics with laboratory practice, and such elements of Natural History as the teachers of each school may be best fitted to give; and if, in addition to the above changes, Latin could be rationally studied for about two years as part of the required course for graduation, these schools would be vastly more useful to the large numbers whose education ends here, and would also be better able to prepare

students for admission to scientific and technical schools, and that without in the least departing from their legitimate work. Much of the work now done in our first year should be done in these schools, and could be, if the changes indicated were made, without much increasing the average age at which students now enter the Institute. The gain to the High Schools as well as to us can hardly be over-estimated.

Degrees. One hundred and twenty-six students have completed prescribed courses of study, and degrees have been given in years and departments as follows: —

	1868	1869	1870	1871	1872	1873	1874	1875	Total.
Civil Engineering	6	2	4	8	3	12	10	10	55
Mechanical Engineering .	1	2	2	2	1	1	4	7	20
Mining Engineering . . .	6		2	5	4	2	1	6	26
Architecture						1	1	1	3
Chemistry		1	1	2	3	6		1	14
Physics								1	1
Science and Literature . .	1		1			1	2	2	7
Total	14	5	10	17	11	23	18	28	126

For the names of the Alumni, with present residence and occupation, so far as known, see Appendix, pp. 200–205.

Your attention is particularly invited to this list, as furnishing the best evidence of the estimation in which the work of this School is held by the public. We have every reason to be gratified by the record of the graduates of our first ten years.

Lowell Free Courses of Instruction. In the establishment of the School of Industrial Science of the Institute, two distinct objects were contemplated: —

First, regular four years' courses of study having special ends in view, and leading to graduation; and

Second, courses of instruction for those who could not command all their time, to be given mainly in the evening, and under such conditions as would secure the attendance of those having the proper preparation to profit by them.

Thus far in the history of the school this second department has been supported by the Trustee of the Lowell Institute. Each year, in the month of October, the courses to be given are announced, with the conditions of attendance.

These courses, which have always been free, and open to both sexes, are given on pp. 216–218.

During the year instruction in Physics has also been given to the Sophomore Class of Boston University, partly by lectures, partly in the Rogers Laboratory. This instruction has been entirely separate from that given to our own students, and has not in the least degree interfered with either the work or discipline of the school, while the department has been very sensibly benefitted by the increased income; and we anticipate the same good results for the chemical department during the coming year, from the same source. Judging from past experience, we shall be justified in opening more generally the lecture-rooms and laboratories of the Institute for the instruction of outside classes, and advanced special students of either sex, in such departments as have the means and space to give it. The advanced instruction in many of the studies, particularly in the later years, is given to small classes, which would not be incommoded by the admission of such advanced students.

I respectfully ask that you will give this subject the attention which it appears to me to deserve.

Lowell School of Industrial Design. The number of students in this department was 25, the same as in the preceding year. Eleven of these students were young men, and fourteen young women. Three years have passed since the establishment of this department, and it can no longer be considered an experiment. It will be seen from Mr. Kastner's report that fifteen students have been granted "Certificates of Proficiency," and nearly all of them are employed by some of the leading Mills in New England. Many samples of goods from designs made by the pupils, or graduates of this school, are already in the market and have been received with favor.

During the past year a much larger variety of designs have been made. Students have been encouraged to work in special directions, and the results have been marked by greater breadth and character. The execution, almost without exception, even among the newest pupils, is remarkable, and is the best possible evidence of the value of the system pursued, and the skill of the teacher. While the designs may not in all cases exhibit the highest type of excellence or taste, it must not be overlooked that they are the work of beginners and must be judged as such.

In this respect also there will be great improvement when students fail to find desirable places before thoroughly completing the prescribed three years' course of study. Lately painting on tiles, porcelain and furniture has been introduced with every prospect of success. It is expected that gradually the range of the school will be widened, and thus give scope to a greater variety of taste and employment. The foundation is well laid for the building up of a great school of practical Industrial Art. It will aid in educating the public taste and increase the demand which it is intended to supply. I earnestly commend this department to your confidence and support.

The Mining and Metallurgical Laboratories. These laboratories have become so important an element in our courses of Mining and Metallurgy, and are besides so novel in such a connection, that it may not be uninteresting to briefly review them in their origin and progress thus far in the history of the department. From the beginning, vacation excursions to mining regions for the purpose of study by teachers and pupils have constituted an important element in the instruction; and in this systematic way many of the more important centres in the United States and Canadas have already been visited. Not only in each locality have the geology, the minerals, the mode of their deposition and extraction, and their metallurgy been studied, but the opportunities have been used to make collections of cabinet specimens, and particularly of the ores of each

locality sufficient for quantitative study in these laboratories. The most important of these excursions took place in the summer of 1871, when a party of professors and students, twenty-one in number, and nearly all belonging to the departments of Mining and Metallurgy, visited some of the most important points in Missouri, and afterwards spent some six weeks in studying all the more developed centres in Colorado and Utah. It was during this excursion, while observing the wrecks of fortunes strown all over the territories, that the thought occurred to us, that much of this waste was due to a want of practical skill joined with scientific knowledge, and that the opportunity for experimenting upon comparatively large quantities of ores must be furnished to our students during their course, as a part of their laboratory work. After disbanding the party I visited San Francisco, and had the good fortune to make the acquaintance of some skillful practical metallurgists, who were making the examination of ores a specialty, and had built up laboratories for ore-dressing, on about the scale we needed. But the processes were detached, and no attempt was made to represent the best forms and kinds of machinery in use at that time in California for the reduction of gold and silver ores.

I had the good fortune to meet Professor William P. Blake, who not only gave me the aid of his scientific and practical experience, but introduced me to the firm of H. J. Booth & Co., of the Union Iron Works, of San Francisco. Mr. I. M. Scott, of this firm, entered fully into the matter, designed the five-stamp battery now in our laboratory, made drawings for the placing of this and the connecting pieces of apparatus, and also furnished us full illustrative drawings of one of the largest and most complete mining mills in California. The sum charged was not much above the cost of the drawings; the firm making a generous contribution to our laboratory.

These steps would have been fruitless if I had not been so ably and enthusiastically supported by Professors Ordway and Richards. The furnaces in the Metallurgical laboratory were designed by Professor Ordway and built under his direction,

while the Mining laboratory has reached its present state of progress almost entirely through the ability, practical skill, and untiring energy of Professor Richards. Thus, what was a conviction has become a practical reality, and the entire credit for the existence of these novel laboratories is due to the professors whose unfaltering faith in success has made them possible.

It is not supposed that the student's experience, gained in these laboratories in handling comparatively large quantities of ores, will supersede the necessity of that wider and more definite experience which can only be gained at the works; but it is claimed that he is made aware by his failures, if not by his successes, of the difficulties he is sure to encounter in actual practice, and is taught not to despise mere practical skill, but to proceed with great caution, and to enter upon constructions involving large expense only after careful preliminary investigation, such as the experience gained in these laboratories especially qualify him to undertake. Full abstracts of two theses are given, to show more clearly than any statement can do the kind of problems assigned and the labor involved.

The pressing need of these laboratories is more space to properly arrange the apparatus and to accommodate the increasing numbers of students taking these courses.

The Fourth Year Chemical Laboratory. The contents of this laboratory were burned on the evening of November 11, 1875. It has been thoroughly refitted, and is now, owing to the skill of Professor Wing, a model of neatness and convenience. The opportunity has been improved to secure a more commodious balance room, and to make the space at the disposal of the department as available as possible. All the apparatus and materials destroyed have been renewed, except the large collection of analyzed substances, which it will take time to replace.

The Mechanical Laboratory. My last report contained a full account of this laboratory by Prof. Whitaker. Another year's experience has furnished additional proof of its value to students in steam engineering. Some of the evidence will be found in the abstracts of theses by students in this department. We still need a small shop fitted with the usual machine tools.

Department of Architecture. I need only to ask your attention to the report relating to this department, and particularly to the large and varied collections available to both teachers and students to illustrate the several courses of instruction. The instruction in this department did not begin till the fall of 1868, and it may be of interest to you to know how it is now considered by one of our best students, who, after completing the course here in 1874, went abroad to continue his studies. We are often asked whether the advantages for architectural study are not far greater abroad, and it is also to answer this question that I quote a few sentences from a letter of one well qualified to give an intelligent opinion: —

"One thing I am firmly convinced of, and that is that any one who thinks of leaving the Institute and coming abroad at the end of his first year, ought to be dissuaded from it — by main force. He is infinitely better off where he is if he did but know it. In one thing especially the Institute has a great advantage — the freedom and character of the library and collections are so much superior to the advantages we have here. Of course there is an admirable library and fine collections at the School of Fine Arts, but they are not at all times accessible in that they are so far distant from the several *ateliers*, and are protected by bands of red tape. So a student has to depend entirely on the library of his *atelier*, which is at best a small and often an ill-chosen one."

"Another great advantage one has at the Institute is that he has those framed drawings by Brune, Calinaud, Esselier, Tissandier, and Létang always at hand. Here at the *atelier* we have nothing whatever to refer to, and when a drawing has to be rendered it has to be done by guess-work and on general principles each time."

"At the *expositions* of the second class [comprising the students who have been only three or four years at the *École*], I think I am safe in saying that the average draughtsmanship is not so good as the average of

the second year at the Institute. Another advantage is the more practical light in which things are looked at."

It is also true that there has been during the past few years a marked improvement in architecture in this city, making it a more desirable place for the building up of such a school. The student will not fail to find in Boston and vicinity good examples of all kinds of such public and private buildings as he may hereafter be called upon to construct.

It gives me great pleasure to be able to present this satisfactory evidence of the character and success of the department.

Department of Military Science and Tactics. The drill hall and gymnasium, which the aid of friends[1] has enabled us to build, together with some changes in the details of the instruction, seem to have finally settled all difficulties. I am extremely happy to be able to report that the department is in an excellent condition, and that the best discipline is maintained without any more difficulty than any other department meets in securing the same efficiency. I think the present status is substantially supported and approved by all; and it is simple justice to Lieut. Zalinski to say that while enforcing the necessary regulations with strictness, he has retained the respect of his pupils, and won the esteem of all by his unselfish devotion to their interests.

[1] Subscriptions in aid of the Drill Hall and Gymnasium: —

George B. Emerson	$500	E. B. Robins	$25
Wm. B. Rogers	400	Theodore Lyman	25
Kidder, Peabody & Co.,	350	Charles H. Delton	25
James L. Little	200	R. C. Greenleaf	25
Ernest W. Bowditch	150	T. T. Bouvé	25
Bent & Bush	100	M. L. Bradford	25
Wm. C. Peters	100	Joseph P. Ellicott	25
M. D. Ross	100	Frost & Adams	25
J. D. Runkle	100	E. Collamore	25
Henry L. Pierce	75	Charles W. Galloupe	25
John H. Reed	50	Wm. B. Spooner	25
Thomas F. Edmands	50	George P. Denny	20
Henry W. Williams	50	Wm. V. Hutchings	20
Mellen, Williams & Co.	50	Surg.-Gen. Dale	20
J. Iasigi	50	Mrs. Daniel Treadwell	10
Wm. E. Baker	50	J. H. Blake	10
Rufus S. Frost	50	From "Friends"	360
John C. Ropes	50		
George W. Simmons	50	Total	$3,240

The Restaurant. In my last report you were informed that we were trying the experiment of establishing a restaurant, which, if reasonably successful, we should attempt to put on a more permanent basis. This has been done at an expense of about $900.[1] We have now a dining room, a lunch room, a kitchen with store rooms, and caterer's rooms, all suitably furnished. Full dinners are served for thirty-five cents, and board by the week for $3.50. I am fully satisfied that it is the duty of the Institute to maintain this restaurant as a means of promoting the health of students, and of reducing their necessary expenses.

Conclusion. Upon the whole, the year's work has been satisfactory. The gain has mainly been in the improvement of the laboratories, and making the experimental side of the instruction more systematic and thorough. All we need to make the progress in the future as marked as in the past ten years is more space. Some important work has never been properly done on this account. The department of Industrial Chemistry is almost entirely destitute of the proper room for large operations, and work in Organic Chemistry is only done at the expense of the comfort, if not the health, of all in the building. But I must refer you to reports of departments for a fuller statement of their several needs.

I close by thanking teachers and students for their hearty coöperation in the work of the year.

JOHN D. RUNKLE, *President.*

[1] Subscriptions in aid of the Restaurant:—

Joseph S. Fay	$150	James L. Little	$50
S. P. Ruggles	100	Wm. Endicott, Jr.	50
J. M. Forbes	100	E. R. Mudge	50
John Cummings	100	H. P. Kidder	50
E. B. Bigelow	50	From "Friends"	100
H. B. Rogers	50		
M. D. Ross	50	Total	$900

SECRETARY'S REPORT FOR 1874–75.

There have been held during the year twelve meetings of the Society of Arts, at which various subjects of practical importance were discussed.

At the meeting of *Nov. 12, 1874*, Mr. Robert B. Forbes read a paper on the "Tracks for Atlantic Steamers," as a report of his doings as representing the Institute in conference with the Committee of the Social Science Association in regard to the "Maury Lanes." He concludes by saying "Now that we have a steamer leaving Europe and North America on the Atlantic every five or six hours, no amount of argument should be necessary, and no pains omitted, to induce all to adopt the Maury Lanes. Unless steamers adopt some definite lines for going and returning, recent disasters show that size, speed, and elegance of ship may not save from collision accompanied by great loss of life."

Within a few months the loss of over four thousand human lives shows the necessity for more means to save life, and better arrangements to prevent accidents from fire, collision, etc. He advocated more and better boats, rafts, life-buoys, mattresses and belts, and various buoyant contrivances carried by the ship herself; all of these, however well-contrived, may yet be useless if the crew are not rendered familiar with their use by frequent drilling. Any properly constructed raft, well supplied with food and water, would be very likely to save its passengers if in the track of steamers crossing the Atlantic, as the lines, if

adopted, would be only a hundred miles or so wide; a sailing vessel, too, disabled, would know where to send her boats to be sure of meeting a passing steamer. The ship herself should be made invulnerable to ordinary ocean casualties, by double bottom as far as the load line, iron decks, water-tight compartments, boiler spaces cut off from other compartments and from coal bunkers below the load line, donkey engine and boiler far away from ordinary casualties of the main machinery, and pumps so fitted that steerage passengers could be used for their working. In other words, make the ship a life-boat.

He advocated better means of detaching boats from their tackle, the Ammen wooden raft, or the Perry or Monitor raft of vulcanized rubber, the swinging davit, and the substitute of the centre-board for a keel in boats. Means for throwing a line two hundred or three hundred yards should be on all passenger ships and men-of-war.

At the same meeting, Mr. H. P. Langley read a paper on "Artificial stone, and its uses," illustrated by specimens. He confined his remarks to that made by the use of hydraulic cements, lime and magnesia, including the Ransome, Frear, Beton-Coignet, and Sorel processes. Stone made by any of these processes has not come into general use in this country as building material; a few buildings, in Boston and vicinity, have been erected wholly or in part of the Frear stone, and the Beton-Coignet has been used to some extent in foundations, piers, etc.; a stone embodying strength, durability and elegance can be made from Portland or the best American cements and pure silicious sand. Many useful and ornamental articles for domestic use are made by the Sorel process. He also exhibited and explained several grinding machines.

Dec. 10. Mr. John C. Hoadley, of Lawrence, read a paper, illustrated by numerous carefully made drawings, on the "Indicator Diagram and its Interpretation."

The indicator, an instrument invented by James Watt, to show the operation of steam in his engines, was the forerunner of a large class of philosophical instruments for noting and

recording vibrations, from the pulsations of an infant's heart to the throes of an earthquake, and velocities, from that of a gentle breeze to that of a rifle projectile or a ray of light.

The diagram, credited to the same inventor, in which forces are exhibited to the eye under the form of curves, by abscissæ proportional to times, spaces, or volumes, and ordinates proportional to pressures, stresses, strains, or any other similarly related magnitudes, is applied to almost all subjects to which the human mind directs its attention.

The indicator is a small, subsidiary, reciprocating engine, attached to the cylinder of a steam engine, or other similar machine, sharing the pressures, expansions, and forces of the chamber with which it communicates; and expending the work developed in its own cylinder in compressing a spring, and in giving motion to a pencil or marking point, which traces on a slip of paper, moving under it with a known velocity, a curved line which, properly interpreted, discloses much concerning the action of the steam or other fluid in the engine, the adjustment of valves, the adequacy of ports and passages, the tightness of packing, the dryness of the steam, the quantity expended per unit of force, and other important points bearing on the question of economy.

After describing the best indicators in use, he showed how the diagrams were made, and how interpreted; he took up the subject mathematically, analyzing observations of his own made during several years, and drew from them practical lessons of great value.

Dec. 24. Mr. George Woods, of Cambridge, made a communication, illustrated by a model worked by steam and water, on his new process for drying lumber and other materials in a natural and rapid manner. The old process of drying lumber in the open air requires from six to ten years, and the consequent loss of time and capital stimulated inventors to devise quicker processes, and various drying rooms have accordingly been in use, with more or less success. In the usual method of forcing a current of air through a room heated to about 150°

Fahr., from partial ventilation the drying was found to be imperfect, causing irregular shrinkage and consequent inequalities in the wood; the steam pipes were carried under the lumber, and the air forced to pass over it, drying the outside first, the interior remaining damp from the air being saturated with moisture. He uses steam pipes under the lumber, but the moisture which is driven by the heat into the containing chamber, instead of being carried off with great loss of heat by the ventilating current, is condensed by cold water constantly running in pipes through the chamber into a grooved channel below, by which it escapes. The moisture is thus gradually, uniformly, and constantly withdrawn from the wood, which dries regularly, without strain on the outside or cracking on the inside. He claims that he can accomplish in six days what the ordinary drying room requires three weeks for, and with much better results; he saves three quarters of the time and utilizes all his heat, and the moisture once out of the wood can not get back.

Mr. N. M. Lowe made some remarks, illustrated by photographs, on the "Leaning Tower of Pisa," adding his testimony in support of the general belief that the tower was not built so, but has sunk from imperfection in the foundation, aided by the yielding character of the soil. Its height is nearly two hundred feet, and its diameter thirty feet; it leans from the perpendicular about thirteen feet, but, as the centre of gravity falls within the base, the structure will not fall unless there be further sinking of the foundations.

Mr. H. P. Langley made some remarks on various mechanical devices, which have of late years made their appearance in this community, achieving for their inventors a short-lived success, and for their users and purchasers vexation and pecuniary loss, with especial reference to steam boilers.

Jan. 14 and 28, 1875. Mr. H. McMurtrie presented portions of a wooden casing which had surrounded a steam pipe at a hotel in this city, showing how wood may be charred by steam used for heating purposes at a distance of an inch from the iron

pipe. Many mysterious fires may owe their origin to this cause.

Mr. Thomas S. Hall, of West Meriden, Conn., made a communication, illustrated by an extensive series of working apparatus, on his system of automatic electric railway signals, for the prevention of accidents from head and rear collisions, misplaced switches, open drawbridges, and railroad and highway crossings, dispensing with the steam whistle, and lessening the number of workmen required, an automatic electric power taking the place of careless and forgetful human agents. The usual way has been to allow a certain interval of *time* to elapse before one train is permitted to succeed another. This system is exceedingly defective, as, if an accident or detention occur, the engineer behind has no reliable means of knowing where the preceding train is; even the electric telegraph, from the carelessness or inexperience of operators, may, as in a recent case, fail to give warning in time to prevent collision.

Mr. Hall's system substitutes for this an interval of *space*, trains being kept a mile apart as indicated by his automatic signals, rendering collision impossible, avoiding the multiplication of tracks, and allowing the much more frequent despatching of trains. The block system, used in England, requires a great number of men day and night, and many accidents have happened under it.

In Mr. Hall's system the road is divided into sections of about a mile in length, at the ends of which are placed two signals, one red, to denote danger; the other blue, signifying caution. When all is right, the red signal should be out of sight, and the blue signal exhibited. As the train passes the first, it raises it, at the same time removing the blue signal, which is about 1000 feet ahead. The red signal then prevents the next train from approaching too near, while the blue signal shows the engineer that the red signal has been displayed. About 600 feet beyond the blue signal, the train reverses the signals of the previous section, or those of a mile and a third back, thus allowing the next train to approach.

Only two instruments are employed, one to enable the train to close an electric circuit, and the other to display a signal to show when this circuit has been closed. He showed his system in operation, of full size, explaining the electrical mechanism; it was seen that a red signal always remains up after a train until it is a mile and a third distant, and that, if all is right, the engineer should see neither the red nor the blue signal, but only the empty windows of the signal frames. The battery, which should consist of about twenty cups to the mile, is kept on an open circuit, except when a train is passing, and the consumption is thus comparatively small.

Should a wire break, or any accident happen, the only result will be that the caution signal will remain visible, and the engineer be thus notified to take care.

The system has been introduced on many of the principal railroads of the country, and on several in this vicinity.

February 11. Mr. A. W. Sprague, of Quincy, read a paper on "Automatic Regulation of Heat and Ventilation," exhibiting operative models of a draft-damper for furnaces and stoves, and also of a ventilator, both working automatically from the heat of the room.

The present devices for controlling drafts of heaters by what are known as "*back* checks" are known to be a prolific source of disease; by them the free exit of the poisonous anthracite gases is prevented, and these are forced out, and pass along with the heated air up into the apartments warmed. He thinks that the combustion should be controlled by *front* drafts, and that the opening and closing of dampers should be automatic, operated by the heat of the rooms warmed. Several devices have been in use for this purpose, worked by the direct heat of the furnace, but such a variable element could not be depended on. In this device the power which works the damper is controlled by a small cylinder of confined air placed in the apartments warmed, which, like an engineer, shuts or opens the damper when the heat of the room goes above or below the point at which the instrument is set. His ventilator operates

upon the same principle, ensuring a pure air, relieving from all watching of drafts, and preventing waste of fuel. They were exhibited in successful operation at the meeting, worked by the heat of the room.

Several members of the senior class of the school, in the department of Mechanical Engineering, then read papers describing their experiments with various pieces of apparatus, to determine some of the properties of steam on a practical scale. The subjects illustrated were superheaters, the Corliss engine, calorimeter and surface condenser, steam gauges, thermometers and pyrometers, and indicators, bearing upon various mechanical, physical, and chemical problems of practical importance.

Feb. 25. Mr. Alfred R. Payne, of Lynn, read a paper, illustrated by a large number of models and diagrams, on "Boiler Explosions," showing the causes of the disasters, and the position assumed by the fragments.

1. Among faults in *original construction*, he drew attention to bad welds, to collapsed flues from insufficient supports, to large boilers improperly stayed, to bad shaped boilers, and such as had no compensation for a large man-hole in the shell. 2. From *frequent and ill judged repairs.* 3. *From weakness, in ordinary working*, principally from external and internal corrosion, especially due to leakage. 4. From *shortness of water.* 5. From *over pressure*, from inoperative or absent safety valves.

For the four years ending June 1870, there were in Great Britain 219 boiler explosions, by which 315 persons were killed and 450 wounded; the greater part of these would have been prevented by proper inspection; very few were caused by shortness of water. He mentioned also many American explosions, including that of the ferry boat Westfield, in 1871. In 1870, there were in this country 118 explosions, by which 326 men were killed and 227 injured; in 1871, there were 93, with 313 killed and 281 injured; in 1874, there were 105 explosions, with 183 killed and 199 injured.

March 11. Mr. Charles W. Spurr read a paper, illustrated by an extensive series of specimens, on patent papered wood-hangings, to the improvement of which he had devoted several years.

About forty years ago the invention of veneering led to the use of thin layers of the valuable woods as a substitute for the solid wood. Attempts to apply veneers to house walls, on cotton or canvas supports, did not prove successful. Then the sheets were laid directly upon plastered walls; they were cut from a log revolving against a horizontal knife in continuous sheets; it was necessary to put them on green, and the ends consequently cracked on drying, while the centre moulded; they were so tender that it was very difficult to handle them, and the process fell into disrepute.

His improvement consists in covering the back of each sheet, as it comes from the cutting machine, with fine, strong Manila paper; this gives a surface to which the wood firmly adheres, and which clings everywhere to the plastered wall in all its irregularities. The paper is applied to alternate sides of the wood, so that corresponding edges come together, forming a regular pattern, without waste of material or useless expense. The wood and paper are united with pure flour paste, and are applied to the wall with the same. Steam and furnace heat have no effect upon them; frost and dampness will not injure them; they will neither shrink nor swell, and can be washed; and they strengthen the plastered wall, and prevent its cracking.

The rolls are cut by a rotary veneer-cutting machine, revolving on two different centres, cutting in the form of an ellipse; it makes from six to fourteen revolutions per minute, gaining in power what is lost in speed; it cuts sheets twelve feet long, the width varying with the size of the log. Walnut and other open-grained woods are cut one hundred and twenty-five sheets to the inch, while maple is cut to two hundred. They have been tried in this vicinity sufficiently to test their durability.

March 25. Mr. Horace McMurtrie read a paper, illustrated by diagrams and models, on the "Governing Principles of the Screw Propeller, practically considered."

If we imagine the shaft of the propeller, with a screw on its extremity, to be a bolt with a thread on its end, and the surrounding water to be a solid immovable nut, it will be understood, in a general way, how by the revolution of the shaft and screw, the vessel is propelled forward or backward.

In the application of power to the propulsion of vessels, part of the effect is lost by the instrument of transmission. In the common paddle wheel this loss is made up of *slip* plus *oblique action* — in the feathering wheel, of *slip* plus *drag* — and in the screw, of *slip* plus *friction* of the surface on the water. The surface of a screw blade may be supposed to be generated by a line revolving around a cylinder at right angles to the axis, at the same time moving along it. The "pitch" of a screw is the advance made by it in a complete revolution in the direction of the axis; in actual practice the full convolution is never used, but only a fraction, say one tenth of the entire pitch for each blade, the number of which varies from two to four. By changing the angle of the blade to its axis, the pitch can be increased or diminished.

The main loss of effect is due to *slip*. Water being movable, a portion of the power of the screw is lost in imparting motion to this water in an opposite direction to the advance of the vessel. The recession of this watery fulcrum is called the *slip*, which is measured in per centums of the speed of the screw. He illustrated the nature of slip, by the action of a man pushing a cart in loose sand. As the man pushes the cart forward, the sand, which is the fulcrum of the power, yields backward to the pressure of the feet, and the cart, instead of advancing the length of a step for each step, which it would do were the man pushing on rock, would advance only the complement of the length of the step, after deducting the distance receded by the sand. Each step, whether on sand or on rock, causes the man an equal expenditure of labor; in the latter

case, the labor being all utilized in giving motion to the cart, while in the former a portion is uselessly expended in giving motion to the sand.

The resistance of the screw may be increased, and the slip thereby diminished, other things being equal: 1, by increasing the diameter of the screw; 2, by diminishing the pitch; 3, by giving the screw an expanding pitch from the anterior to the posterior edge of the blade; 4, by increasing the fraction of the pitch used; 5, by employing two equal and similar screws, one under each quarter; 6, by increasing the depth of immersion.

April 15. Mr. A. D. Blodgett, a student of the Institute in the department of Mechanical Engineering, read a communication on an "Automatic Electric Burglar Alarm," of his own invention.

This he explained, and exhibited in operation attached to doors and windows, so arranged that the opening of one or the raising of the other, would not only ring an alarm, but, in connection with an electric annunciator, indicate the room in which the burglarious attempt was made.

His device combined both the open and closed circuits. It is very simple, there being no clock work to be wound up, as is sometimes the case with closed-circuit alarms, and there is no machinery to increase expense or to render repairs necessary. As there are three wires running to each door and window, a burglar would not know which to cut and which to connect, which he might in a closed or open circuit; as all the wires come through the same aperture in the casing, it would be almost impossible to tamper with them successfully. If all three wires are cut the alarm is sounded.

Mr. Martin then exhibited in operation, and described a "type writer," a machine to supersede the pen in manuscript writing.

In size and appearance it resembles a sewing-machine; writing is performed by touching small round keys, like those of a piano, arranged in four rows of eleven each, and may be done by one or both hands; each key, on the top of which the letter

or sign is indicated, by depression with the finger causes its letter to be printed on the paper by means of a lever. Any one who can spell can write with it, and any quality or length of paper can be used, from three to eight inches wide. The type receives ink from a moving ribbon, which can be used for months without being re-inked, and with proper usage will last a year. Its work is as legible and as uniform as print; its average speed is twice that of the pen, and one good operator is as good as two expert penmen for all purposes except book-keeping and writing in books. For lawyers, reporters, copyists, clergymen, the blind, and for those whose hand writing is illegible from age or any other cause, such a machine is of great value. Any one with two weeks' practice can write with it faster than with a pen. By using copying ink and the manifold process, with thin papers, twenty copies can be written at a time. For teaching spelling and punctuation in schools it is of advantage, and its use would be like play to a child.

April 29, and May 13. Mr. George B. Dixwell read a paper, illustrated by diagrams and tables, on "Cylinder Condensation," and the means of suppressing it, in steam and vapor engines. The conclusions he arrived at after a large number of experiments, extending over several years, and verified in the Mechanical Laboratory of the Institute.

His first object was to show that this condensation was of great importance as a difficulty to be overcome, and to do this he examined the published experiments of Chief Engineer Isherwood, about one hundred in number, made on fifty different engines.

Since the time of Watt, engineers have been trying in vain to realize all the theoretical advantages of working steam expansively, and it was supposed that cylinder condensation was the cause of their failure; the loss from this cause was shown, at about a half cut off, to be about forty per cent. of the steam utilized, thus disappearing more than one half of the gain expected from expansion; clearance, back pressure, and friction would take off more, so that the gain would be very little; with

a shorter cut-off it is worse, and there may be absolute loss instead of gain.

Being satisfied of the importance of cylinder condensation, the next question was how to suppress it, and to ascertain what had been or could be done by steam jackets, and the system of compounding. He showed that the saving by jackets was really very small.

He explained how he thinks it comes to pass that cylinder condensation is different at each cut-off, that the actual amount should be many times the equivalent of that directly due to the conversion of heat into work and radiation, and that the condensation in the higher pressure cylinder of a compound engine should be much less at the same cut-off than that in the low pressure cylinder.

He then explained how he had come to the conclusion, which he thought entirely new, that the action of the metallic surface is *cumulative*, causing the total condensation to be several times that caused at each stroke by the conversion of heat into power, and by radiation. Even in the best compound engines there is a loss by condensation of 20 per cent. of the steam utilized; he showed how their performance may be increased some 35 per cent. by an expenditure of 10 per cent. of heat, and this by superheating. He explained how the vapor of water is, unlike air, one of the best radiators and absorbers of heat, and how a film of steam converted the polished metallic surfaces into an energetic radiator. Steam may be superheated sufficiently to balance the radiation and the heat converted into work, without fear of its carrying into the cylinder a temperature injurious to the working parts. The expense of such superheating is trifling, cylinder condensation is suppressed, and the gain is about 25 per cent. in compound engines.

There how been no elections during the year. Five members have died during the year. Messrs. Hammatt Billings, Samuel Hooper, James Lawrence, Charles G. Putnam, and N. B. Shurtleff; twenty-three have resigned, and six have been

dropped for non-payment of fees. The list now comprises 68 life, and 200 associate members.

The attendance at the School of Industrial Science for the year has been 288, as follows: Resident Graduates, 21; Regular Students of 4th year, 35; of 3d, 45; of 2d, 55; of 1st, 86; — Students not candidates for a Degree; 4th year, 15; 3d, 18; 2d, 24; 1st, 5; Architectural Students, 26; Students in Practical Design, 25, of whom 14 were females. Total 288, of whom 12 were graduates of other Institutions. Of these, about five-sixths were from Massachusetts, principally from Boston and its vicinity; — from other New England States, 17; viz.: from Maine, 7; New Hampshire, 3; Vermont, 2; Rhode Island, 2; Connecticut, 3. From other States, there were from New York, 9; Ohio, 7; Illinois, 6; Pennsylvania, 5; Indiana, 4; New Jersey, Minnesota, and California, 2 each; Tennessee, Kentucky, Michigan, Iowa, Nebraska, Colorado, British Provinces, Japan, Canary Islands, 1 each; Hawaiian Islands, 5.

Thirty-four professors and teachers have been connected with the school, and, as usual, several advanced students have rendered assistance in the laboratories and in surveying. The fees from students have amounted to about $47,000, a decrease of $3000 from the previous year.

The class in the School of Design has been full, and eminently successful. For details, see the Report of Mr. Kastner, on page 34.

The Lowell Free Courses for the year were as follows:

I. *General Chemistry.* Twenty-four laboratory exercises of two hours each, on Wednesday and Saturday afternoons at 2½ o'clock, by Professor Nichols, beginning Saturday, Nov. 21.

II. *Qualitative Analysis.* Twenty-four laboratory exercises of two hours each, on Wednesday and Saturday afternoons at 2½ o'clock, by Professor Nichols, beginning Saturday, Nov. 21.

III. *Practical Geology of the United States.* Eighteen lectures, on Tuesday and Friday evenings at 7½ o'clock, by Dr. T. Sterry Hunt, beginning Tuesday, Nov. 17.

IV. *Lantern Projections.* Eighteen lectures on the use of the Lantern as a means of illustration in teaching, on Wednesday and

Saturday afternoons at 3½ o'clock, by Professor Pickering, beginning Wednesday, Nov. 18.

V. *Elementary French.* Eighteen lessons, on Monday and Wednesday evenings at 7½ o'clock, by Instructor Jules Luquiens, beginning Monday, Nov. 16.

VI. *Modern Philosophy from Descartes to Hegel.* Eighteen elementary lectures, on Monday and Wednesday evenings at 7½ o'clock, by Professor Howison, beginning Monday, Nov. 23.

VII. *Elementary Principles of Mechanism.* Eighteen lectures for machinists, on Tuesday and Thursday evenings at 7½ o'clock, by Professor Lanza, beginning Tuesday Dec. 7.

Open to both sexes over eighteen years of age; applicants to apply in their own handwriting, stating age, occupation and previous preparation.

The Corporation has held six meetings during the year.

At the meeting of April 14, 1875, it was voted that the students of the Boston University may receive instruction in Chemistry at the Institute on payment of a certain sum to the Department.

At the same meeting it was voted that the Professorship of Geometry, Stereotomy, and Drawing be vacated at the end of the school year.

At the meeting of June 9, 1875, it was voted to confer the Degree of Bachelor of Science on the following students, who had complied with all the conditions:

Allen, Samuel E. . .	Fall River . .	Dept. of Civil Engineering.
Burrison, H. K. . . .	Boston . . .	" " "
Church, Christopher A.	New Bedford .	" " "
Dodge, Frank S. . .	Beverly . . .	" " "
Dorr, Edgar S. . . .	Mt. Auburn . .	" " "
Edes, William C. . .	Bolton . . .	" " "
Hammatt, E. A. W. .	Newton Centre .	" " "
Handy, Edward A. . .	Barnstable . .	" " "
Howes, Clar. L. (1873)	Hanover . . .	" " "
Huntington, Wm. F. .	Springfield . .	" " "
Sargent, Welland F. .	Sedgwick, Me. .	" " "

Head, James H.	Brookline	Dept. of Mechanical Engin'ng.
Hibbard, Thomas	W. Roxbury	" " "
Knapp, J. Austin	Hanover	" " "
Lewis, Wilfred	Philadelphia, Pa.	" " "
Plimpton, Thomas D.	Walpole	" " "
Sargent, Francis T.	Malden	" " "
Stanwood, James B.	Cincinnati, O.	" " "
Burnett, Moses D.	Syracuse, N. Y.	Dept. of Mining Engineering.
Goodale, Chas W.	Hudson	" " "
Oxnard, Benj. A.	Jamaica Plain	" " "
Shockley, Wm. H.	New Bedford	" " "
Warren, H. L. J.	Boston	" " "
Webster, Wm. R.	Philadelphia, Pa.	" " "
Wrinkle, L. F. J. (1870)	Lee	" " "
Boyden, Amos J.	Foxboro'	Architecture.
Kinnicutt, Leonard P.	Worcester	Chemistry.
Mixter, Samuel J.	Boston	Physics.
Arnott, James L.	Thompsonv'e, Ct.	Science and Literature.
Prentiss, Wm. A.	Holyoke	" "

The subjects of the Theses, and abstracts of the same, will be found on p. 105.

The progress of the School in the various departments will be found in the reports of the President and Professors.

SAMUEL KNEELAND, *Secretary.*

Boston, Oct. 9, 1875.

DEPARTMENT OF PHILOSOPHY.

To the President: —

During the year just closed, the changes in the course of study proposed at the end of the preceding one have been matured and put in operation. By alterations in the course for the school at large, my work with the regular students of *all* departments has been limited to two lectures a week during the whole of the First Year, and three a week during the first half of the Fourth Year. The changes in the Department of Philosophy itself, have amounted to carrying its leading subject a half-year backward, so that it now begins at the opening of the Second Year. In this way, the time allotted to the study of the Modern Systems has been extended, so that it now covers the Third and Fourth Years entire. The particulars of the Course as it now stands may be gathered from the last catalogue. Details of the work done in the two sections of my department are herewith submitted.

I. THE WORK WITH ALL REGULARS.

First Year's Class. During the first half-year, there were lectures and exercises twice a week on the Classification and Analysis of Terms, and the Structure and Analysis of Sentences. During the second half-year, the same number of lectures was given upon the Rudiments of Logic, including the Classification of Propositions — their Notation, Reduction, Opposition, Conversion, and Permutation — and the Elementary

Principles of Inference. As this was our first attempt at teaching Deductive Logic to First Year men, it is worth while to state that the experiment has been quite successful. At the annual examination in May, the class proved themselves to be well acquainted with all the general forms and principles of deductive inference, and showed a creditable skill in detecting the ordinary fallacies. But to secure the best results from the work now assigned to the First Year, it is desirable that we shall have a better preparation. For this reason, I would call the attention of the Faculty to the recommendation made in this connection last year, and would ask that it be adopted and put in operation when the next class is admitted; namely, that all candidates for the First Year's class be required to pass an examination in the Analysis of Sentences and the Classification of Terms.

Fourth Year's Class. During the first half-year, a course of three lectures a week was given to this class upon the following topics: the Elementary Principles of Inference; the Idea and General Divisions of a Philosophy of Science; and the Nature of Induction, with an account of its Recognized Methods. The lectures were accompanied by a study of Mr. Fowler's text-book on Inductive Logic. The interruption of our work at the middle of the preceding year, made it necessary to take part of this year's time to bring up the lost topics; consequently, the subjects proper to the Fourth Year had to be presented more briefly than our regular plans contemplate. With the next class, I shall be able to carry out the course in the Philosophy of Science as laid down in the catalogue.

II. THE WORK WITH STUDENTS OF PHILOSOPHY.

In the department proper of Philosophy, there have been this year nine students — three regular and six special — an increase of four over the year preceding. The changes involved in bringing the course of study for this department into the form now given in the catalogue, have ranked all the regulars as

students of the Third Year. Of the specials, three took the philosophical studies of the Third Year, and the remaining three the course in Psychology belonging to the Second Year. These last read with me the more important parts of Mr. Jardine's recent treatise on the *Psychology of Cognition*, which, including as it does a very good sketch of the various theories of Perception from Descartes to Kant, gave them a valuable introduction to the whole field of philosophy.

The regulars and specials of the Third Year have covered the ground assigned in the catalogue. They have thoroughly read the following matter: —

Descartes' *Method*, and his six *Meditations*, entire;
Spinoza's *Ethics*, in outline;
Leibnitz's *Monadology*, *New System of Nature*, *Nature of the Soul*, and *Doctrine of a Universal Spirit*, entire;
Locke's *Essay*, in its most important parts, with Cousin's Critique of the same;
Berkeley's *Principles of Human Knowledge*, entire;
Hume's *Inquiry Concerning Human Understanding*, — the first eight sections.

In addition to making and studying notes of my explanations and criticisms, the class have read from Schwegler's *History of Philosophy* the accounts of the systems of Descartes, Geulinx, Malebranche, Spinoza, Leibnitz, Locke, Berkeley, and Hume, together with Stirling's notes on the same, and Ueberweg's accounts of most of these systems. On Berkeley, they have read, besides, Fraser's *Introduction*, and the *Prolegomena* and *Notes* (by Ueberweg and others) contained in Krauth's edition of the *Principles*. The results of their examinations have been very gratifying. Specimens of the papers used during the year are subjoined.

EXAMINATION ON LEIBNITZ.

1. Brief narrative of Leibnitz's career. His principal works, etc.

2. Items of agreement between Leibnitz and the Cartesians, and between Leibnitz and Spinoza.

3. Points of vital difference between Leibnitz and both of these.

4. What specific difficulties felt in both of the previous systems was the Theory of Monads intended to overcome? In how far does it succeed? What difficulties does it leave still unsettled?

5. Sketch the Theory of Monads. [Definitions — Exposition of their Nature, Relations, and Gradations — the "City of God."]

6. State Leibnitz's peculiar argument for God's existence.

7. Name and state the Three Working Principles of Leibnitz's System.

EXAMINATION ON BERKELEY.

1. Titles of Berkeley's principal works, with the date and burden of each.

2. Clear and full outline of his *Principles*, including its parts, and the contents of each part.

3. What, according to Berkeley, constituted the currently received principles? What, exactly, does he mean by the expression, "principles of knowledge"?

4. What are the principles that he proposes to substitute? With what general school does his fundamental principle connect him?

5. In what sense, and in what sense only, does Berkeley deny the existence of Matter? Rebut the common objection of "plain absurdity," charged upon his view.

6. What, exactly, is Berkeley's doctrine a theory concerning? What point against the common theory does he unquestionably establish? What depth hid in the common view does Berkeley's fail to appreciate?

7. How, precisely, does Berkeley's theory differ from Malebranche's "Vision in God"?

8. Sketch Berkeley's several arguments for the insubstantiality of Matter? What does he mean by his perpetual reiteration that matter is merely "phenomenal," or that its "*esse* is simply *percipi*"? Into what contradiction, or at any rate obscurity, does he fall, when pressed with the apparent *discontinuity* which his doctrine introduces into na-

ture? What ambiguity here comes to light in Berkeley's use of the term *idea*?

9. State Berkeley's argument for the existence of God.

10. What does Berkeley think he has *demonstrated* concerning Matter and concerning God?

11. Criticise each of his arguments for the insubstantiality of Matter. Show that, in two of them, he practically begs the question, and how; and that, in the other two, he strikes wide of the mark, or, as the logicians say, commits *ignoratio elenchi*.

12. Reflect on Berkeley's argument for God's existence, and then endeavor to state *completely*, all the principles it implies. Give an estimate of it in the light of your results.

13. What, in the second grand division of his treatise, does Berkeley unquestionably succeed in showing?

14. What does he attempt to show in the Third Part? What estimate would you put upon his success here, and why?

15. What permanent contribution may Berkeley be said to have made to Modern Philosophy? In whom, however, did a conscious insight into this view first arise?

16. Compare Berkeley's doctrine with the Cartesian; show their difference upon formal points, but their essential identity in failing to solve the problem of intercommunion between Subject and Object.

17. Compare Berkeley's view with Spinoza's; show from what standpoint it has the apparent advantage over the latter of preserving the identity of the Individual Soul and its distinctness from God; but show, also, from what standpoint it loses this advantage entirely. Point out the contradiction in Berkeley's thinking, which is here implied.

18. What remarkable passages in the *Principles* seem to penetrate to a philosophy which, while thoroughgoing idealism, would fathom the insight, deeper than Berkeley's, contained in the common view? Why cannot this deep view be credited to the *Principles* as a system?

ANNUAL EXAMINATION, May 29, 1875.

Write a connected sketch of the history of Philosophy, from Descartes to Hume inclusive, giving the systems of Descartes, Spinoza, Leibnitz, Locke, Berkeley and Hume. Be especially clear upon the following matters:—

1. The essential and distinguishing principle of the whole modern philosophic method.

2. The relations of the several systems to each other, and to the modern philosophic movement as a whole.

3. The exact statement of those points in the several systems which the ordinary reader is pretty sure to misapprehend, but an error about which will prevent any real insight into the systems.

4. The characterization of each system as a whole; the statement of the points upon which it has attained to permanent views; and the criticism of its errors and failures.

5. The tracing of Cartesianism through its various attempts to solve the Problem of Certitude consistently with its preconceived principles; including, particularly, the extensions of Descartes' doctrine made by Geulinx and Malebranche.

6. In the case of Leibnitz, the conception of the Monads, the Gradations of Existence, and the Three Principles of Thought.

7. In Locke's case, the exact point rendering him of lasting significance in the history of philosophy.

8. In Berkeley's, to show just how he differs from the ordinary view, just what he means by his "Idealism"; and to refute the vulgar objections to his theory, though criticising it.

9. In Hume's, to be full upon his critique of Causality, and his application of its results to the doctrines of Providence and Moral Obligation.

Respectfully submitted,

GEO. H. HOWISON.

DEPARTMENT OF ENGLISH AND HISTORY.

President Runkle:—

I hereby transmit through you to the Government of the Institute the following account of my classes and lessons during the past school year.

To the second class, I gave a course of lectures on the history and literature of the latter half of the Eighteenth Century. Attendance on these lectures was compulsory, but early in the term, owing to the pressure of their scientific studies the time assigned for writing up notes was taken away. A good deal of voluntary writing was, however, done by various members of the class, and a considerable number gave a voluntary attendance on a continuation of the course through the second term.

To the third class, I gave a course of lessons on the history and text of the U. S. Constitution, with such references to English constitutional history as time allowed. Attendance on these lectures was compulsory and at the close of the term the class was examined on the text of the Constitution, but time enough was not allowed for more extended study of the subject out of the class-room.

During the second term nearly the whole of the class gave a very regular and constant voluntary attendance on a course of lectures on the Elementary principles of Political Economy and its connections with History.

At the request of a majority of the members of the fourth class, I read with the whole class some of the more important chapters in Prof. Parsons' work "The Laws of Business for Business Men," especially those on the law of contracts, a subject which was assigned to the students in "Science and Literature" only. Study was not compulsory, but the students generally bought the book and a considerable number passed a good examination in the parts gone over. The subject is out of my province and should be in the hands of a legally educated instructor.

With a small number of students in the department of "Science and Literature" who have attended my lectures I have done a good deal of collateral reading in History and Political Economy, accompanied on their part by a considerable amount of writing. The theses of two graduates in this department, that of Mr. Prentiss, on the condition and resources of the Empire of Austria, and that of Mr. Arnott on Switzerland are herewith presented.

The Elementary exercises in Rhetoric and Composition which I have heretofore given to the first year's class, were this year omitted to make room for exercises in the department of Logic and Philosophy. I cannot but express my regret that more time cannot be found for all the classes for study and writing in connection with the exercises in my department, and that efficient assistance cannot be afforded me in the laborious work of examining written work.

Respectfully presented,

W. P. ATKINSON,

Professor of English and History.

DEPARTMENT OF MODERN LANGUAGES.

President Runkle:—

DEAR SIR, Permit me to submit to you the following report of the department of Modern Languages, with especial reference to its operation during the past year.

I. FRENCH REQUIREMENT FOR ADMISSION.

This is one of the most important matters relating to the department, and has occupied much of the attention and time of the same. It is now three years that French has been among the requirements for admission. During the past two years the amount required has been the same, viz., "French Grammar through Regular and Irregular verbs, and twenty-five pages of easy reading," *i. e.* the more prominent forms and laws of the language with some practice in reading. The first year (1873) French was required for admission the amount was less, viz., "The first nineteen lessons of Otto's grammar," *i. e.*, the elements of the language as far as regular verbs. The following table gives the results of these three examinations.

1873.	1874.	1875.	
70	41	71	No. taking French in First Year.
53	49	53	Average per ct. at Entrance Examination.
15	5	3	No. admitted without French.
49	26	51	No. admitted without conditions.
81	63	81	Average per ct.
21	15	20	No. admitted with conditions.
10	19	32	Average per ct.

From this it appears, 1st, that the number of those without French has decreased each year; 2d, that notwithstanding the increase in the amount required, the average of the whole class at the examination in 1875 was not lower than in 1873; 3d, that the average of the lowest portion of the class, who had to be conditioned, has been increasing each year; 4th, that the number of those admitted without conditions has slightly increased, while that of those admitted with conditions has slightly decreased.

The experiment therefore of requiring a co amount of French for admission, that is of having so much of what was previously done in the school made a part of the preparatory work, seems to have been thus far reasonably successful. Still there is very great room for improvement in the quality of the work. There are too many cases now where cramming is evident, and too few where the ground has been well and systematically gone over and thoroughly digested. With the view of facilitating the preparation in French and improving the character of the same, we would offer a few suggestions to be printed in the Annual Catalogue in respect to the manner of treating the French at this stage of its study, thinking that they may be of assistance to instructors and private students.

The amount of French at present required for admission, if well done, would be equal to at least two thirds of a year's work at the Institute, so that certainly there is a prospect of the time when French may be discontinued at the end of the first year, and a full two years' course in the language be regarded as completed. After such a course of practice and training it is probable that students would be able to read easy French at sight and have sufficient strength to solve with accuracy such difficulties as might arise. For the sake of giving a better idea of how a class now stands at the end of the first year, we subjoin the French examination paper at the Annual of the last First Year, the average of the class of thirty-nine students on the same being 56 per cent.

In regard to the *French requirement for the future*, it seems to us desirable to increase somewhat the amount of reading matter, so as to afford a larger field for the observation and study of the grammatical principles. We would therefore, leaving the amount of Grammar as it is, propose sixty pages of easy French instead of twenty-five as at present, and indicate this by "the first two books of Voltaire's 'Charles XII.' (*i. e.*, about sixty pages) or the equivalent of the same."

In the report of this department for last year it was stated that much inconvenience and loss attended the union in one class of students so unequally advanced as were those in the First Year's class of the year before in French. It was suggested also that an *Elementary Class* consisting of those behindhand be formed, to recite by themselves and oftener than the rest. This plan has been carried out the past year and has worked to the great advantage of both parts of the class. This class (consisting of twelve students) had four exercises a week, three being outside of school hours, it being impossible to find time otherwise that would not conflict with regular school duties. At the Semi-Annual this class was merged with the regular one. A like class (consisting of thirteen students) has been formed for the present year. Poor preparation, which makes such a class necessary, is perhaps at first a necessary consequence of a new requirement for admission. But it should be dispensed with as soon as possible by requiring the full amount of candidates before they are allowed to enter. It would certainly seem that after this students who have no French, though prepared in other subjects, should be required to make up by means of private instruction before being admitted.

It is too late now to go back and inquire whether it would not have been more advisable to require *Latin instead of French for admission*. Out of sixty-five students in the class just entered, forty-five report that they have studied Latin and twenty-two that they have not; fifty-one were from schools where Latin was a branch of study and sixty-three from schools where French was. It seems hardly consistent with this to suppose

that a Latin requirement would have been more easily obtained than a French one. Moreover, although it cannot be doubted that the student having a knowledge of Latin to start with would advance much more rapidly on that account in his French, still it is hardly probable that he would get so far at the end of a year as if he had started with a corresponding amount of French. It seems therefore fair to conclude that the requirement of French for admission saves time for other work in the school without being one harder to fulfil than Latin would be.

Of course we do not mean to imply by this that Latin would be of no value to the student at the Institute. On the contrary, it would be of very great value to him, in view of the general culture afforded by its study on the one hand, and its practical bearing upon the various departments of science on the other. It becomes therefore an important subject for consideration whether, in addition to the French, a certain amount of Latin may not sooner or later be required for admission.

II. WORK OF THE PAST YEAR.

This has been conducted nearly in accordance with the revised scheme of studies arranged year before last, that is a two years' course in each of the studies, French and German. The following indicates the disposition of this time:—

French. { Before entrance. / I Year. / II " (1st half)

German { II Year (2d half). / III " / IV " (1st half).

The number of hours in each of these courses is one hundred and eighty, which however includes the time occupied by Intermediate, Semi-Annual and Annual examinations. Three hours a week have been used for both courses, this number, it is believed, producing the best results. This amount of time is certainly not large for the French. For the German it is decidedly small, when the difficulties of the language are considered, and the amount of practice necessary to obtain any readiness in reading. If the French requires two years, two and a

half years are certainly not too much for the German, if the student is to advance as far in the same.

During the past year the First Year's class has had French; Second and Third Years' classes German. The Fourth Year's class had German the first half of the year. The Second Year commenced German, contrary to the above scheme, at the beginning of the year as heretofore, instead of waiting until the French was finished, it being the intention to have the French finished the first half of the fourth year in the time assigned to the German. It was felt that, if the German were commenced later, students would not be able to use it in their professional work in the school. It seems to be however undesirable to intermit the French for two years and then resume it for half a year, and better to finish it at once, even if the time for commencing the German should have to be postponed.

Regular dictation exercises have accompanied the recitations, so also regular exercises on the forms and principles of the language. The First Year had read at the Annual two hundred and twenty-five pages, from Otto's French Reader, Mérimée ("Colomba"), and Lacombe ("Petite histoire du peuple français"). The Second year read during the year extracts from Whitney's German Reader, and from Andersen's "Märchen." The Third Year had read at the Annual (*i. e.*, during two years) two hundred and four pages, from Whitney's Reader, Putlitz ("Badekuren"), Zschokke (Wirtshaus zu Cransac"), and Heyse ("La Rábbiata"). The Fourth Year read during the first term portions of the "Goetz von Berlichingen" of Goethe, and of the "Lügen" of Benedix. The average of the Third Year class, of forty-four students, at the Annual on the annexed paper in German was 66 per ct.

The above are the regular courses in French and German for all the students. The "Science and Literature" students of the Third Year had an advanced course in French, in which the "Atala" of Chateaubriand and two plays of Molière were read.

The "Science and Literature" students of the Fourth Year read during the second half from Goethe's "Goetz von Ber-

lichingen," and had also a course in the Science of Language, Whitney's "Language and the Study of Language" being used as a text book.

In the Second year there has been an optional class in French reading, numbering twenty-eight students the first term and twenty-one the second, there being two exercises a week with no time for preparation. Most of About's "L'homme à l'oreille cassée" was read the first term, and portions of "Visites au Jardin d'Acclimatation" by Barr, the second term. The object of these optional readings in French was to remove the objections attending the intermission of the French for two years.

There has been also during the year an optional elementary class in Spanish, composed of students of the Third and Fourth Years, with two exercises a week, no outside work being required. This class numbered ten the first term, and seven the second. For the present year an opportunity will be given to students of the same years to take Italian. In future we would suggest that this class be confined to half of the year, and an hour's preparation be required for each one of the two weekly exercises.

The number of exercises a week in all the studies of this department has been thirty-one the first term, and thirty-two the second.

III. TECHNICAL READING.

Strictly technical reading is quite out of the question in a class composed of students from several departments, for the practical reason that a student in one department does not need the technical words of another. Moreover, the instructor could not be expected to have the proper knowledge of the technicalities in various departments in French and German, any more than in English. On the other hand a student has a special advantage in beginning such reading under the guidance of a Professor in his own department, and with the illustrations at hand which a laboratory affords. This is more especially the

case with the German, where a brief introductory course, for learning technical words and the general style of technical reading is quite necessary, even though a student be well advanced in general reading. Such strictly technical reading has not been attempted in the regular classes. It has however to some extent been carried on by some of the students under the direction of the Professors in the departments concerned.

But if strictly technical reading is not practicable in the regular courses, it is proper to inquire whether scientific reading of a general nature would not be more profitable than something in general literature, as having more or less bearing upon the professional work of the students. This kind of reading has been tried to a limited extent the past year in both French and German, and with such success apparently as to warrant replacing the general reading in a great measure by the same. Perhaps, aside from the practical difficulty of obtaining the proper material for such reading, the only objection to having the entire reading of the student of this nature, is the danger that there would not be variety enough for him to observe the uses and styles of the language as they appear in the various kinds of literature.

IV. MODE OF STUDYING THE MODERN LANGUAGES.

The views of the department on this point remain the same as stated in the last report, only strengthened and confirmed by experience. A thorough grammatical training seems to us essential, if one would understand a language. Without such training and study he cannot expect accuracy and strength in the interpretation of the same. Studying a language indeed, and studying its grammar, must go hand in hand, if the term grammar be taken in its proper sense. The study of Grammar, it is true, has from abuse come to convey to the mind of the student the idea of cramming the memory with certain dogmatic and technical statements not connected with a living organism; while he is further discouraged by having put before

him at the same time what, though of the highest value in its place, belongs to the department of logic not language. But let him consider that grammar is the methodical embodiment of the facts and laws of a language and that, when by actual observation of, and practice on the language itself he is getting possession of its laws and facts, he is studying its grammar. He will then find that he is growing in knowledge of the language in proportion as he is mastering these facts and laws, and that his study has the attraction of the study of any science. The material of a language, consisting in its words, is also essential, but no more so than the principles which teach one how these are used. Our aim has accordingly been to accompany the exercises with methodical statements of the principles as they are indicated by the text. Of course there is danger of going too far in this direction, to the sacrifice of the material and the practice. But if a mistake were made in either direction, it seems to us that it would be safer to make it in the direction of little practice and the acquisition of few words, than in that of an inadequate knowledge of the structure and laws of the language.

Very Respectfully,

Dec. 17, 1875. CHARLES P. OTIS.

[EXAMINATION PAPER IN FRENCH OF THE FIRST YEAR AT THE ANNUAL.]

Translate. — I. On appelle *colons* à cette époque, des hommes qui cultivent la terre d'un propriétaire moyennant une redevance fixe qui s'élève au quart ou à la moitié des fruits. Les colons sont, comme on voit, des espèces de métayers, mais des métayers perpétuels. Le maitre ne peut pas les chasser, et eux, en retour, ne peuvent pas quitter le domaine. On les tient pour personnes libres, mais il faut entendre libre au regard du maître et en ce sens qu'ils ne lui doivent que des redevances fixées ; d'ailleurs, ils sont esclaves de la terre à laquelle ils sont attachés, serfs de la glèbe, comme on dira plus tard. S'ils s'enfuyent, le maitre pourra les faire reprendre.

LACOMBE.

II. Dès qu'il eut quitté le tillac, la femme de chambre remonta, et, après avoir fait subir un interrogatoire au matelot, rapporta les renseignements suivants à sa maîtresse : la ballata interrompue par la présence d' Orso

avait été composée à l'occasion de la mort du colonel della Rebbia, père du susdit, assassiné il y avait deux ans. Le matelot ne doutait pas qu' Orso ne revînt en Corse pour *faire la vengeance*, c'était son expression, et affirmait qu' avant peu on verrait de la viande fraîche dans le village de Pietranera. Traduction faite de ce terme national, il résultait que le seigneur Orso se proposait d'assassiner deux ou trois personnes soupçonnées d'avoir assassiné son père, lesquelles, à la vérité, avaient été recherchées en justice pour ce fait, mais s'étaient trouvées blanches comme neige. "Il n'y a pas de justice en Corse, ajoutait le matelot, et je fais plus de cas d'un bon fusil que d'un conseiller à la cour royale. MÉRIMÉE.

III. Orso, répondit Colomba, chacun honore ses morts à sa manière. La *ballata* nous vient de nos aïeux et nous devons la respecter comme un usage antique. Madeleine n'a pas le *don*, et la vieille Fiordispina qui est la meilleure voceratrice du pays, est malade. Il faut bien quelqu'un pour la ballata.

Crois-tu que Charles-Baptiste ne trouvera pas son chemin dans l'autre monde si l'on ne chante de mauvais vers sur sa bière ? Va à la veillée, si tu veux ; j'irai avec toi, si tu crois que je le doive, mais n'improvise pas ; cela est inconvenant à ton âge, et . . . je t'en prie, ma sœur. MÉRIMÉE.

IV. Il va poser une première pierre à Corte ; je m'imagine que ce doit être une cérémonie bien imposante, et je regrette fort de n'y pas assister. Un monsieur en habit brodé, bas de soie, écharpe blanche, tenant une truelle . . . . . et un discours ; la cérémonie se terminera par les cris mille fois répétés de *vive le roi !* — Vous allez être bien fat de m'avoir fait remplir les quatre pages, mais je m'ennuie, Monsieur, je vous le répète, et par cette raison je vous permets de m'écrire très-longuement. MÉRIMÉE.

V. (*Passage not translated in class.*) — Pendant le repas, le chef de la loi m'avait fait faire plusieurs questions par Joseph : il voulut savoir pourquoi je voyageais, puisque je n'étais ni marchand, ni médecin. Je répondis que je voyageais pour voir les peuples, et surtout les Grecs qui étaient morts. Cela le fit rire ; il répliqua que, puisque j'étais venu en Turquie,[1] j'aurais dû apprendre le turc. Je trouvai pour lui une meilleure raison à mes voyages, en disant que j'étais un pèlerin[2] de Jérusalem. Il fut pleinement satisfait. La religion est une espèce de langue universelle, entendue de tous les hommes. Ce Turc ne pouvait comprendre que je quittasse ma patrie par un simple motif de curiosité, mais il trouva tout naturel que j'entreprisse un long voyage pour aller prier à un tombeau.[3]

CHATEAUBRIAND.

1. Explain the pronouns *eux*, *laquelle* (V) ; *m'(ennuie)*, *m'(écrire)* (II).

2. What is the tense in "dès qu'il m'eut quitté"? Is there any rule as to the use of this tense ?

[1] Turkey. [2] Pilgrim. [3] Grave.

3. Explain the form of the past participle in "*ils sont attachés*," "*s'étaient trouvées*," "*m'avoir fait remplir*," giving the rule of agreement in each case.

4. What mode and why in *Orso ne revint* (II), *que je le doive* (III), *que s'entreprisse* (V)?

5. Give the principal parts of *doivent* (I); *subir* (II); *faut* (III); *écrire* (IV); *entreprisse* (V).

6. State when the past participle remains invariable.

7. What verbs can be followed by an infinitive without any preposition?

8. When is the compound of present chiefly used? Of what other tense may it at times take the place?

9. What is the difference of meaning between *aussi* at the head of a sentence and after a verb; between *puis*, *puisque* and *depuis*; between *ailleurs* and *d'ailleurs*?

10. What would be the construction in French of these two sentences: *I believe I am right* and *I believe he is right*?

Translate.—1. The danger in which he finds himself is great. 2. Your tale[1] amused me; tell it to him also. 3. The letter which I have begun to read is badly written. 4. We obtained peace[2] by making sacrifices. 5. The qualities of Alexander were those of a king, his faults those of a soldier. 6. I lent him all the aid[3] I could. 7. It does not seem that you love him. 8. I do not doubt that your Majesty will learn with pleasure that I have discovered a world. 9. I could not prevent him from falling. 10. He was ready to go up to his room when some one knocked at the door.

[1] conte (m); [2] paix (*f.*); [3] assistance (*f.*).

FIRST YEAR. MAY, 1875.

[EXAMINATION PAPER IN GERMAN OF THE THIRD YEAR AT THE ANNUAL]

I. Vielleicht wären alle diese aufgezählten Ursachen der Dürre und Wärme nicht hinlänglich, so beträchtliche Theile der afrikanischen Ebenen in ein furchtbares Landmeer zu verwandeln, hätte nicht irgend eine Naturrevolution, z. B. der einbrechende Ocean, einst diese flache Gegend ihrer Pflanzendecke und der nährenden Dammerde beraubt. Wann diese Erscheinung sich zutrug, welche Kraft den Einbruch bestimmte, ist tief in das Dunkel der Vorzeit gehüllt Humboldt.

II. Folgt auf die brennende Hitze des Tages die Kühlung der, hier immer gleich langen Nacht, so können Rinder und Pferde selbst dann nicht sich der Ruhe erfreuen. Ungeheure Fledermäuse saugen ihnen, während des Schlafes, vampyrartig das Blut aus; oder hängen sich an dem Rücken fest wo sie eiternde Wunden erregen, in welche Mosquitoes, Hippoboscen und eine Schaar stechender Insecten sich ansiedeln. So führen die Thiere ein schmerzenvolles Leben, wenn von der Gluth der Sonne das Wasser auf dem Erdboden verschwindet. Humboldt.

III. Mit dem Eintritt in die Südbonauländer erfolgten Angriffe der hier wohnenden Bulgaren; sie tödteten manchen Pilger mit ihren Pfeilen, spießten einzelne Gefangene und

wurden erſt geſchreckt, als Kaiſer Friedrich ſtreng das Wiedervergeltungsrecht ausübte, und eine ihrer Städte Brandiſium zerſtören ließ. Auf die Griechen fiel wegen dieſer Feindſeligkeiten zunächſt kein Verdacht, weil man ſehr gut wußte, daß die eingewanderten Stämme ihnen nicht gehorchten; als aber Gefangene bekannten, daß man die Bulgaren allerdings von Konſtantinopel aus angereizt habe, entſtand Argwohn, welcher noch höher ſtieg, da die Fürſten von Servien und Racſna dem Kaiſer bei Nizza perſönlich aufwarteten, für Lebensmittel ſorgten und zugleich ihre treuen Dienſte gegen die ſtets ränkevollen Griechen anboten.

Raumer.

IV. (Passage not read before.)

Noch ungefähr eine halbe Stunde fuhren die Reiſenden die glatte, ebene Schauſſee entlang, dann bogen ſie ſeitwärts ab in den dunkeln Wald, durch den ein gutgehaltener Fuhrweg lief. Die Sonne zeigte ſich bereits in voller Pracht am Himmel und blickte verwundert lächelnd auf die Erde, die ohne Vorwiſſen ihrer hohen, leuchtenden Protectorin ſich über Nacht einen prächtigen Brillantſchmuck angeſchafft hatte. Nach Mitternacht war ein ſtarkes Gewitter über die Gegend gezogen; es hatte viel geregnet, noch hingen ſchwere Tropfen an Bäumen und Geſträuchern und fielen rauſchend auf das Wagenverdeck, wenn der Poſtillon mit der Peitſche einen niederhängenden Aſt berührte.

Marlitt.

[1] Highway.

1. Prin. Pts. of zutrug (I); ſaugen, verſchwindet; (II); ließ, fiel, anboten (III).

2. Give in full t' Fut. Act. and Pass. of verwandeln (I). How would wird gehüllt differ fr gehüllt (I).

3. As what pa ch may the infinitive be used, and how is it then treated. What is put before it, when it is used to express a purpose. After what verbs is zu not used with the infinitive.

4. Explain the subjunctives hätte (I), angereizt habe (III); explain the tense of the latter. State the main divisions of the subjunctive.

5. Construction of Theile, Gegend, Pflanzendecke (I); gleich, Nacht, Ruhe (II); Wiedervergeltungsrecht, ihnen, (von Konſtantinopel) aus (III).

6. Analyze the following words, hinlänglich, afrikaniſch, furchtbar, Vorzeit (I); ſchmerzenvoll (II); Süddonauländer, Wiedervergeltungsrecht, Feindſeligkeiten (III); stating which are compound and which derived, and the force of the suffixes.

7. What *endings* of nouns denote the feminine gender. Nouns of what *signification* are feminine. Illustrate from the texts.

8. Give the corresponding English for zählen, tragen, Kraft, Zeit, hüllen (I); Rücken, Thier (II); treten, ſtören, ließ, wiſſen, horchen (III).

9. Distinguish between wann, wenn; welcher, der; aber, ſondern; erſt, zuerſt; Staat Stadt; kopf, Haupt.

V. 1. John's books are still lying on the sofa in the drawing-room, and he has gone out riding. 2. I am afraid that our expected guests will stay away to-day, because it is bad weather. 3. I think that I have read too long, for my eyes pain me very much. 4. Come to our house to-morrow, if

you wish to see my father; but you must be there punctually, for he goes out at eight o'clock. 5. My friend dines with me on Sunday, which habit he has had for years. 6. He said that they were in the same town the whole summer through, without seeing each other a single time. 7. I have had to act thus, because my brother wished it; in this matter I am determined not to act against his wishes. 8. Our whole family was yesterday evening at a concert at Mrs. S.'s, where there was much dancing. 9. Can you remember how his summer house by the river side looked? 10. Without heeding [1] my express [2] commands, he has run away, in order to amuse himself somewhere, [3] or to attend to [4] his own affairs.

[1] achten auf. [2] ausdrücklich. [3] irgendwo. [4] besorgen.

DEPARTMENT OF MILITARY SCIENCE AND TACTICS.

President J. D. Runkle: —

SIR, In this my report for 1875, the centennial year of the first battles of the Revolution, I may be pardoned for adverting to the importance of causing a certain degree of military instruction to be given, side by side with instruction in the arts of peace. The fruits of the latter can only be fully assured to us, by ability to defend them against aggression. I can not do better than quote the words of Washington: —

(From Inaugural Speech, April 30th, 1789.)

"Among the many interesting objects which will engage your attention, that of providing for the common defense will merit particular regard. To be prepared for war is one of the most effectual means of preserving peace.

"A free people ought not only to be aroused, but disciplined; to which end a uniform and well digested plan is requisite;" * *

(From Speech to both Houses of Congress, Dec. 3d, 1793.)

* * * * * * * * * * * * *

"I cannot recommend to your notice measures for the fulfilment of *our* duties to the rest of the world, without again pressing upon you the necessity of placing ourselves in a condition of complete defense and of exacting from *them* the fulfilment of *their* duties towards *us*. The United States ought not to indulge a persuasion that, contrary to the order of human events, they will forever keep at a distance

those painful appeals to arms, with which the history of every other nation abounds. There is a rank due to the United States among nations, which will be withheld, if not absolutely lost, by the reputation of weakness. If we desire to avoid insult, we must be able to repel it. If we desire to secure peace, one of the most powerful instruments of our rising prosperity, it must be known that we are at all times ready for war." * * * * * * * *

Until the entire nature of the human race has become changed, it will be necessary to provide for defence against armed aggression by foreign nations, and also against internal attempts to subvert our liberties. On political and economical grounds it is undesirable to maintain a large standing army. It is then to the people, *en-masse*, that we must trust for defence. To do this effectively, experience has shown that they must be provided with capable instructors and leaders, officers.

These would naturally be selected from the most intelligent and educated citizens, from the graduates of our institutions of higher learning. The wisdom of legislation which requires military instruction to be given in institutions receiving a certain public bounty is obvious.

Permit me to quote from a letter written by President Andrew D. White of Cornell University.

"The law, as it now stands, enables at least one collegiate institution in each State to send out every year, a body of men with a good substantial knowledge of military matters, to aid in keeping up citizen soldiery, and to be of use in various communities, in case of emergency. Of course, the highest military education in the country must be given at West Point. But the instruction given to the country under the slight expense caused by the existing law, is, it seems to me, a matter which any statesman should take care of.

"It has always seemed to me that the control of citizen military organizations should be kept, as far as possible, in the hands of the more thoughtful and better educated classes. I dread to see the day arrive when, with the civil commotions sure to arise in a Republic as wide in extent, and as thickly settled as ours is to be, the thoughtful men and the educated men will be shrinking in corners for want of

the simple elements of military knowledge, and military organizations for emergencies will be entrusted to men of little or no character and standing. Take the Rebellion — we had, then, an opportunity to note the advantage gained for the Confederacy by the fact that so many of their better educated men had some military training at their schools and colleges.

"As a Professor at the University of Michigan, I saw the other thing. I saw at that institution our very best young men — and the best were the very first to enlist — go forth under the charge of a drunken blackguard, taken out of a lager beer saloon, his only title to command being that, in all that community, he was the only one who had any military knowledge, he having been a non-commisioned officer during the Mexican war. The result, I need hardly tell you, was disastrous. This company of noble young men melted away, and the captain was one of the few who came back.

"I have thought much upon this, and it seems to me that the clause in the Bill of 1862, providing for military instruction in the various State colleges, and the supplementary legislation since, allowing the detail of the army officers to conduct this education, showed real statesmanship.

"In view of emergencies which are sure to arise, sooner or later, in a Government like ours, may I not ask you to give this matter your careful consideration, and to see, if possible, that a provision in all respects so beneficent, be not destroyed."

Unfortunately, there is a tendency to construe this law and to meet its requirements in a manner so antagonistic to its spirit, that the amount of good derived therefrom is reduced, most frequently, to a minimum.

In all wars, the loss of life by disease far exceeds that resulting from actual combat. It is therefore essential that, first of all, instruction be given how properly to care for the health of troops when subjected to abnormal fatigues and exposure. *This should commend itself simply on the ground of humanity, as it is for the purpose of preventing suffering and loss of life.* War, at best, is horrible. It is inevitable in the affairs of all nations. Let us deprive it of its stings and horrors as far as human foresight, based upon experience, will admit. In our

eagerness to acquire material prosperity, let us not close our eyes to the dangers and contingencies of the future, however far removed they may seem at present.

Besides the instruction as to the care of the health of troops, it is necessary to instruct in the mode of organizing, disciplining and drilling troops, not alone in the actual details, which may be changed from time to time, but also in the general principles involved and their *rationale.*

The Military Instruction during 1874-5.

The instruction during the year ending May, 1875, was satisfactory, when one considers the many drawbacks arising from limited time and a lack of hearty support to the work of the department. This was made apparent by the written examinations and closing drill. The students were, apparently, very much interested. The officers performed their duties in an efficient manner. Commissions were given, at the closing exercise to the following:

Staff Officers ranking as First Lieutenants.

Adjutant: G. F. Swain.
Quartermaster: E. H. Gowing.
Signal and Ordnance Officer: J. Kirk.
Captains: F. E. Peabody, C. H. Morton, W. Jenney, A. G. Everett.
First Lieutenants: H. J. Monroe, W. M. Peters, C. H. Fisher, I. M. Story, F. P. Spalding.
Second Lieutenants: W. A. Frost, C. F. Lawton, E. G Faber.

The warrants of the non-commissioned officers were presented at the same time. No commission or warrant will hereafter be given to any student who has not shown a capacity for performing efficiently the duties of the office conferred, or one of higher grade, in actual service.

Voluntary Encampment.

On May 31st, 1875, twenty (20) students accompanied me for a week, in a voluntary encampment near Lexington, Mass.,

on grounds belonging to the Hon. John Cummings. The tents and camp equipage were loaned to us by the courtesy of the Adjutant General of the State. The camp was laid out and the tents were pitched by the students. They here put into practice some of the makeshifts of camp life, which enable soldiers to make themselves comfortable under unfavorable circumstances. The regular duties of the camp were performed by the students early in the forenoon and late in the afternoon, thus giving them the greater portion of the available day for their own recreations. Voluntary exercises of day and night signalling, and target shooting, were given. Parties of two or three were detailed to cook certain articles of food in the same manner and with the same facilities that soldiers in the field would be apt to have. All these experiments were successful. The relaxation afforded by this encampment, after the severe mental tax imposed by the annual examination, greatly benefited all. This was evidenced, if in no other way, by the excellent appetites and increased weight of every student who participated in the encampment. Our thanks are due for many courtesies extended by inhabitants of Lexington. The conduct of our students was, throughout, unexceptionable. The fears that were expressed, that discredit might be brought upon the Institute by the reckless conduct which but too frequently characterizes encampments, were without foundation. On Sunday, all attended Divine Service except those who were required to take charge of the camp. It is my desire to repeat this at the close of the next year. May not this be advantageously extended to all classes, accompanied by some of the Instructors, and be, in so far, an extension of the general system of the school in giving technical instruction? Much useful instruction might thus be given in the laboratories of nature. The civil engineering students might have exercises in various kinds of surveying. A week might be advantageously spent in geological work. For this purpose the locality of the encampment might be changed from year to year. Botanical instruction

might be imparted in the woods and fields. With all this, opportunities would be secured for out of door sports; relaxation, so necessary after the severe strain imposed by the annual examinations, would be given. Useful instruction and experience would be gained in the makeshifts of camp life and in the preparation of food in the field.

The Military Instruction during 1875-6.

As so much of the school year of 1875–6 has elapsed at the time of making this report I will extend it sufficiently to cover the time up to date of writing.

The principal objections which presented themselves to the Faculty and some of the students against the military instruction as it was, were, that after entering the second year, it interfered with the strictly professional work of the students; on my own part, that I could not give a sufficient amount of the theoretical instruction in the duties of officers and yet have the *battalion* as well drilled as it should be. With all this in view, desirous alike of seeing the military instruction established on a basis which would be unobjectionable, of receiving the support of the Faculty, and of being able to attain better results, I proposed the following plan, at the opening of the school year, based upon the understanding that the Corporation and Faculty had, *conjointly*, allotted the *time* of two hours per week for two years, to military instruction: —

1st. (a.) That the drill should be obligatory only during the first year, but for *three* hours, instead of *two*, per week.

(b.) Permit such second year students, as volunteer, to drill. I should be likely to get only such men as would be competent and desirous of performing the duties of officers.

(c.) Have the battalion organized as two companies instead of four. Allow the officers (second-year students) a small deduction of tuition fee for performing their duties. Have these appointments subject to the control of the Faculty, in order that no student be permitted to occupy an office, the duties of which

would prevent his attending properly to his studies. By this system I felt confident that the drill and discipline of the battalion, at the end of the year, would be better than in previous years.

2d. Require second-year students to attend exercises of one hour per week, either lecture or recitation, in subjects pertaining to the duties of officers; about one-third of these exercises would be lectures, two-thirds recitations. The lectures would require, on an average, one-half hour of not very hard reading in preparation. Objections having been made that by this plan, more time would be given than before, on account of time required for preparation, allowance was made for this, and the number of exercises for the second year was reduced to twenty-four (24). The results have been eminently satisfactory, both Faculty and Students apparently acquiescing in this arrangement, as being the best solution which could be arrived at, based upon the premise that military instruction shall be given and received in good faith. It is desirable that this shall be recognized as its permanent *minimum* s' cus.

The following is the roster of acting commissioned officers at the present date.

Staff Officers ranking as First Lieutenants.

First Lieutenant and Adjutant: E. F. Williams.
First Lieutenant and Quartermaster: J. Kirk.
First Lieutenant, Signal and Ordnance Officer.
Captains: I. Rich, D. Pierce.
First Lieutenants: L. O. Towne, E. S. Draper.
Second Lieutenants: E. C. Miller, A. T. Lincoln.

The Gymnasium and Physical Culture.

The outfit of the Gymnasium of the Institute is tolerably complete, and requires but a few pieces of apparatus to make it as complete as any in this vicinity. A large proportion of the students have availed themselves of it. But now that we have the Gymnasium, one step further seems desirable, *i. e.*, the adoption of a system of *obligatory* gymnastic exercises. The

students who most need physical exercise are the very ones who least take it, either in the gymnasium or elsewhere. The mind cannot be used advantageously unless the body is in good condition. The Faculty of the Institute prescribe certain studies and methods of study, which, in their judgment, will ensure the greatest mental vigor and greatest amount of mental acquirements. It, therefore, seems a vital omission not to also prescribe such physical exercise as will place the body, and consequently the mind, in the best possible condition to sustain the burden which is put upon it. As the mental instruction given at the Institute is but the foundation upon which its students are to build after graduation, it would seem but a natural and necessary complement of the work of the school, so to exercise and develop their bodies, as to send them forth physically, as well as mentally, strong. The mental strength which may be acquired at the cost of the physical can avail but little, wasting itself prematurely in its feverish efforts to realize itself. Engineers, as a rule, do not have the opportunities to distinguish themselves by great works until after they have practised their professions for years, and shown their capacity by successfully performing many works of minor importance and magnitude. Their calling demands an incessant exercise both of body and mind. How important, therefore, that they should be duly strengthened for their work, by such preparation of the body as the experience of years has shown to be feasible and profitable. It may be said that the time of the students is so much taken up as to make it impossible to assign any time for a regular physical exercise. It will be found more profitable to *make* this time. Require every student to participate daily in an exercise of from fifteen to twenty minutes, and I have but little doubt that fewer complaints will be made of excessive burdens being imposed in their studies. These exercises should be of such a nature as to improve the respiration and to impart a general tone of health in the entire body, developing in harmony all parts and functions of the body. They may be comparatively light in their nature,

and should be given under the direction and supervision of a physician, in order that no student, however weak, may be injured by any inordinate or misdirected exercises. The introduction of obligatory physical culture into the curriculum of the Institute can hardly be considered in the light of an uncertain experiment. A system of such culture has been in active operation at Amherst College for nearly fifteen years. In this connection I would quote the following extracts from a report on that subject, by Dr. Nathan Allen: —

"In President Stearns' Report to the Trustees for 1859, the health of the students again constituted a prominent topic. He says, 'time and experience have convinced me of an imperious demand, in the circumstances of an academic life, for immediate and efficient action on this subject: many of our students come from farms, mechanic shops, and other active occupations, to the hard study and sedentary habits of college. Physical exercise is neglected, the laws of health are violated, the protests and exhortations of instructors and other friends are unheeded. The once active student soon becomes physically indolent, his mental powers become dulled, his movements and appearance indicate physical deterioration; he makes occasionally spasmodic efforts to regain his former elasticity by exercise, but by finding discomfort more than advantage from it, he eschews exertion and becomes more inert than ever.

"'By the time the Junior year is reached, many students have broken down their health, and every year some lives are sacrificed. Physical training is not the only means of preventing this result, but it is among the most prominent of them. If it could be regularly conducted, — if a moderate amount of physical exercise could be secured as a general thing to every student daily, I have a deep conviction, founded on close observation and experience, that not only would lives and health be preserved, but animation and cheerfulness, and a higher order of efficient study and intellectual life would be secured. It will be for the consideration of this Board, whether, for the encouragement of this sort of exercise, the time has not come, when efficient measures should be taken for the erection of a Gymnasium, and the procuring of its proper appointments. It is a settled conviction in my own mind, that only by a certain amount of regular exercise

together with attention to other laws of health, can that listlessness and dullness and inefficiency which is so hostile to good scholarship and so common among students, be overcome.'" * * * *

The following are mentioned as some of the results of the system of required physical exercise which was adopted a short time after the publication of the above mentioned report.

"1st. There has been a decided improvement in the very countenances and general physique of the students. Instead of the pale, sickly and sallow complexion once very commonly seen, with an occasional lean, care-worn and haggard look, we now witness very generally, fresh, ruddy and healthy countenances, indicative of a higher degree of vitality, and thus the vital currents, enriched by nutrition and oxygen, have a free and equal circulation throughout the whole system. * * * * * * * * * * *

"2d. In the use of the limbs and the body,—in the physical movements and conduct of students generally, there has been, we think, decided improvement. * * * * * * * *

"5th. A comparison of the present health of students with what it was ten or fifteen years ago, shows a surprising improvement. It is rare now for any student to break down suddenly in his health, or to be compelled to leave college on this account. In 1855-6-7 and 8 such cases were common, as may be seen by referring to the statements of President Stearns in the opening of this paper; and the truth of the statements is moreover confirmed by others personally conversant here for twenty or thirty years. As no record was formerly kept of the amount of sickness from year to year, or of the number of students leaving college on account of illness, no exact comparison on these points in figures can be instituted. But the experience and observation of those who have been on the ground a long time must bear decided testimony to a greatly improved state of health among the students over that of former times; and as for those who once were members of the Institution, and return here on public occasions, they cannot fail to see a great improvement in this respect. * * * * * * * * * * *

"7th. But the most marked evidence of improved health is found in the diminished sickness of every class each year after entering college.

In a table giving the amount of sickness arranged by classes, it seems there has been for these eight years on an average *more than three times* as much sickness in the *Freshman* Class as in the *Senior* Class. It may be said that the students upon first entering college do not know so well how to take care of themselves as they do in the third and fourth years; or that some students who come here feeble and sickly, leave the Institution early, so that the vigorous and more healthy alone remain. This may account in part for the change, but only for a small part of it. For some students who now enter college with slender constitutions encounter considerable sickness the first year, but afterwards improve in health, and in the third and fourth years are comparatively well. And the number now leaving college during the first and second years, on account of ill-health, is very small. Then again, if we compare the sickness or health of a class all the way through college now, with that of one ten or fifteen years ago, a surprising difference will be found; if the sickness did not then increase or keep up through the whole course, it certainly did not diminish so much in the second and third years and almost entirely cease in the fourth, as is the case now. * * * *

"There is still another very important consideration, viz.: has the standard of scholarship in college been raised by means of gymnastics? As the system of marking, or mode of exhibiting this standard was changed a few years since, an exact comparison in figures cannot here be instituted; but it is the decided opinion of the Registrar, (the College Officer who has charge of these statistics,) that there 'has been an elevation of rank within the past few years.' It may be that some individuals in a class formerly reached as high scholarship as any now do; but the *aggregate* scholarship of a whole class, we are confident, is higher now than it once was, and, to say the least, is much easier obtained, with fewer hours of study, and less loss of health and life. * * * * * * * * *

"Said President Felton to the writer, shortly before his decease, referring to the gymnastics at Amherst which he had just witnessed: 'Such a system of physical exercises thoroughly understood and applied by the members of Harvard University, would aid me in the matter of discipline in that Institution more than anything else.' We are here authorized to state, that the faculty of Amherst College have found great assistance in government from this source; — that since

the introduction of this department, the cases requiring discipline have been far less numerous, and more easily managed, than formerly."

Having quoted some of the most essential portions of this admirably written report, wherein the opinions of the *governing authorities* of the college have been cited, I submit, likewise, a letter written by the *students*, viz;—

"Testimony in favor of the Gymnasium.

"Amherst College, June 14th, 1865.

"The class of 1865, having completed its studies in Amherst College, desires to express its high appreciation of the physical culture which it has received under the direction of Prof. Hitchcock. As this class is the first one in College which has enjoyed through its whole course this physical training, some expression of opinion seems quite proper. There have been ninety-two different students connected with the class, fifty-five of which now graduate; eight have died,—two with consumption, and six in the army from wounds or disease. There is no one of the graduating class but could pass a complete examination for life insurance or admission into the United States Army. From a thorough trial of four years' course of training, we can fairly judge of the system here adopted. Our exercises have been conducted in a well-furnished gymnasium, and always under the direction of the Professor in this department. We have found the required attendance — a part of the system — not at all objectionable, and, what at first in the exercise was a little embarrassing or unpleasant, soon became a positive pleasure. The simultaneous participation of many persons in the same exercises has contributed a lively zest to them, when otherwise they would have proved dull and uninteresting. These exercises have been so varied in character as to be adapted both to the strongest and the weakest student, conducing alike to health, strength and grace of action. The half-hour required for exercise has proved the golden mean between length and brevity of time for this purpose, and has never been considered lost by us, as our health at the close of our college course testifies to the inestimable value of this training. We are confident, if this matter of exercise had been left a voluntary thing, many of our class, who are now strong and healthy, would have yielded to the diseases incident to student life

while others, who were weak and slender boys on entering college, are now strong and vigorous men. Cases of protracted illness have been almost unknown among us, and large numbers in the class have not been detained by illness from a single college duty. Believing that a strong body is the best bulwark to a sound mind — that strong muscles and well-developed limbs are powerful aids to the brain, — and being indebted very much for these results in our case to the physical training we have received in Amherst College, — we give this voluntary testimony to the value of the system of gymnastics here adopted."

"E. P. Frost,
M. K. Pasco,
A. H. Howland, } *Committee.*"

Consideration of these statements and facts, as also that of others which the already too great length of this report prevents me from mentioning, have convinced me of the great importance of adopting similar measures at the Institute of Technology. Whilst the suggestions herein embodied are foreign to my province as military instructor, I felt impelled to make them from my interest in the welfare of the Institute and a deep seated conviction that the adoption of a system of obligatory physical exercises would eventually enhance its efficiency and reputation, inasmuch as its graduates would leave it with unimpaired, nay *improved* health, instead of being physically weakened by their labors. They would be more certain to live long enough to reflect credit upon their Alma-Mater.

Respectfully submitted,

E. L. ZALINSKI,
1st Lieut., 5th U. S. Art'y.

REPORT UPON THE LOWELL COURSE OF PRACTICAL DESIGN, FOR 1874–75.

President J. D. Runkle:—

SIR:—The success of this Department (Practical Design for textile fabrics) has been most flattering during the three years of its existence, terminating in May 1875.

It is provided with all the requisite facilities and novelties necessary for the study of Practical Design. Samples of carpets, oil cloths, silks, laces, cachemeres, shawls, paper hangings, percales, muslins, prints, cretonnes, etc., are received every year, anticipating current styles. Under these favorable auspices, fifteen students have now graduated, eleven of whom have secured situations in different manufactories in the New England States. We have had during the year two public exhibitions of pupils' work, one at Horticultural Hall, Boston, and the other at Lowell, which proved highly gratifying to visitors, and the manufacturers especially.

The advanced pupils have the privilege during each season of showing their designs to manufacturers and frequently succeed in disposing of their patterns. The amount received by students for their designs, in oil cloth and prints, has reached about three hundred dollars. The following is a list of the graduates from this Department, who have received the certificate of proficiency.

James L. Folsom . .	Hartford Carpet Mill., Thomsonville, Ct.
Henry Morse . . .	Carpet Mill, Maine.

Alex. Johnston . . .	Pacific Mills.
Ernest Pierce . . .	" "
Everett Anthes . . .	Manchester Print Works.
Miss Mary Jefferson . .	" " "
Miss Elizabeth Mendum .	" " "
Carroll Faunce . . .	Hamilton Woolen Co.
Charles Cowdery . .	Oriental Print Works.
Howard Hinckley . .	Merrimac Co.
Miss Mary Ricker . .	Hamilton Manufacturing Co.
Miss Annie Barnard . .	No situation.
Miss Kate Simonds . .	" "
Henry Mabille . . .	" "
Edward Williams . .	Lithographer.

Respectfully submitted,

CHARLES KASTNER,

Director.

REPORT ON THE FIRST YEAR'S COURSE IN FREE HAND DRAWING.

President Runkle: —

Dear Sir: — In the courses of Civil, Mechanical, and Mining Engineering, and Architecture, as given at the Institute, one of the most important branches and one which requires a large proportion of time for its thorough acquisition, is Mechanical Drawing; and a proficiency in this branch is one of the most useful and necessary things in after professional life. But in order to become an expert or even a fair draughtsman, a firmness of hand and knowledge of form are necessary, that cannot be obtained by mere mechanical work and can only be acquired by a course of practice in free-hand drawing.

The value of free-hand drawing is very apt to be underrated in a scientific school, but it is absolutely the making of good draughtsmen. And those who are the most proficient in it will always succeed well in their mechanical work. Its value is seen in the execution of all shaded drawings, in good lettering, in the neatness and taste shown in the work, and indeed in every line that depends upon anything beyond a straight edge and pair of dividers.

The subject as given at the Institute is not laid out with any artistic end in view, but it is merely intended to give in the time allotted to it, that portion of elementary free-hand drawing which will be of the greatest use in mechanical work. The first lessons consist in exercises on straight lines, circles, and

simple curves; after which Schubert's plates are taken up, and the remainder of the time spent in drawing from them. These plates consist of lithographic copies of simple machine details. They are all details of frequent use and are taken from the best designs; are correctly and nicely shaded, part by line shading and the rest by simple cross-hatching, and introduce a number of simple forms, so that the student learns from them the application of light and shade to a large variety of surfaces.

The drawings are made upon brown paper, and the crayon point is used in preference to the pencil, as it requires a greater delicacy in the handling and gives a much better effect in a much shorter space of time.

The first term is thus spent in learning the mere execution of outline and shading; but during the second term, some attention is also paid to making drawings of objects so as to show their three dimensions. The first part of the term is then spent in isometric drawing, that being one of the simplest methods of showing bodies in this manner; and the remainder of the term is devoted to free-hand perspective. In both of these subjects, large plates are made of various geometrical solids and hung up at the end of the drawing-room to be used as copies. The drawings then made by the students are shaded by line-shading, the shadows also being carefully put in. Such parts of the theory as are necessary are given from time to time in short lectures preceding the regular exercises.

It would be of great advantage to many students to have some knowledge of sketching, but with the present limited time devoted to drawing, it is impracticable to take up this branch at all, so that the course, as at present arranged, ends with the subject of perspective. The number of plates drawn by each student varies greatly owing to the difference in the rapidity with which they work. A certain number of plates, however, are required, and the students finish as many more as they can. The total number required amounts, in the year's course, to twenty, and the average of the students complete three or four

more, while a few will do eight or ten more; but these latter usually include the best and poorest workmen in the class, so that the number of plates completed is no criterion as to their excellence.

Examinations are held twice a year. At the Semi-Annual, the projections of some solid are put upon the black-board together with its proportions, and the students are required to make a correct drawing from them, both in outline and in shade. A fixed time is allowed them, so that the rapidity with which they work is thus taken into account in determining their mark. At the Annual examination, similar projections are given them to draw from, but this time they are required to make a correct shaded drawing of the object in perspective. And in addition to this a few questions on the theory of the subject are given.

Free-hand drawing requires patience and perseverance more than anything else for its successful accomplishment. A hard working and not particularly talented student usually excels a more gifted but less patient one. But when a student has a peculiar talent for the subject and unites patience and perseverance with it — and there are usually several such in every class —excellent work is the result. So the stan lard of any class in Free-hand drawing is very apt to be the same as its standard in other studies. But there are always a few in every class who appear to be entirely without any ability to draw, though many of them try their best and are faithful in their work; but in all such cases due credit is given for their perseverance. As was said before, the regular course does not aim at teaching anything more than the elements of drawing. But there is a good collection of casts at the disposal of the department, and special students and such regular students as are interested in their drawing, and desire to continue it, have special instruction.

Respectfully yours,

FRANK B. MORSE.

REPORT OF THE FIRST YEAR MECHANICAL DRAWING.

President Runkle:—

In compliance with your request I herewith submit the following report of the manner of instruction and the work accomplished in Mechanical Drawing in the First Year's class of 1874–5.

During the first year the students are taught the use of the drafting instruments and such general principles of Mechanical Drawing as are applicable to all the various divisions of the subject created by the different professional courses. To this end therefore, the work of the year has been conducted. Professor Warren's three elementary works, "Drafting Instruments," "Elementary Projection Drawing" and "Elementary Perspective" were used as text books, and from them the system and examples were chiefly taken. "Drafting Instruments" was the first book taken up, from which various examples having the following ends in view, were selected and drawn. Proficiency in the use of the drawing instruments, familiarity with a few important geometrical problems, the manner of laying on ink and color washes with the brush, the conventional representations of wood, iron, stone, and earth, water sections, and a limited amount of lettering. The latter consisted of three title pages, one for each principal division of the year's work. Seven weeks were given to this subject. Projections were next taken up, under the head of which was included the principles of

shades and shadows, isometric drawing, shading and construction drawing from models and copies. In projections proper were given the mode of representing the plan, and end and front elevations of rectilinear and cylindrical figures, when seen both in parallel and oblique projection; also problems covering the most general cases of the intersection of solids, both by planes and by other solids, together with their developments. The subject of shades and shadows was pursued by first finding the shades of objects and then their shadows when the latter fall on the vertical or horizontal planes of projection, or on both; and secondly, by finding the shadows on oblique abutments and the like, by means of auxiliary planes. Examples were drawn in isometric projection which included the manner of representing isometric and non-isometric lines, circles, and curved lines, together with isometric shadows. At this stage, practice was had in shading with India ink, some of the isometric constructions being made with special reference to this. As this was for pictorial effect only, but little time was devoted to it owing to the amount of work to be done on more important subjects. It is very desirable, however, that the students should have more practice in making highly finished drawings of structure designs and inventions. Much more time than is in my power to allow for the purpose could be profitably employed in this manner. The year's work gone over thus far, was next practically applied by making one or two construction drawings, the examples being taken from the book, from notes, and from the model. This completed the course in projections after thirteen weeks had been spent on the subject. During the remaining ten weeks of the term Elementary Perspective was taken up. Between two and three weeks were devoted to the natural method of perspective drawing as founded on projections. This consists of finding by projections where a visual ray from a given point to the eye pierces the perspective plane. It satisfies in the most natural manner the simplest geometrical definition of the perspective of a given point, viz., that it is where a visual ray from that point pierces a picture plane. This method however, when

applied to any but the most simple objects, complicates the drawing to such an extent that it is not a desirable one to use for practical work. Nevertheless it has a certain value, for it gives to the student a knowledge of the principles upon which the artificial or derivative methods are based. The remaining weeks were given to drawing in perspective both simple and complicated examples, by the methods of diagonals and perpendiculars and of vanishing points.

All the work thus described was drawn on uniform sheets of twelve and one half, by eight and one half inches in size, and at the end of the year were bound in neat paste board covers. Besides this course from the text books, at the end of each of the following subjects, additional drawings from notes and models were made on sheets eighteen, by twelve and one half inches in size. Immediately following the elements of drawing as taken from "Drafting Instruments," drawings were made on one of these sheets which served both as a review and as an application of all previously gone over. Following projections proper, a sheet was filled with a few simple applications of the subject to the drawing of patterns for constructions in sheet metal, and the like. A large and complicated line drawing, with its shadow falling on both planes of projection, was constructed from the model as a review of shades and shadows. Two large shaded drawings in perspective completed the year's work in Mechanical Drawing. These review plates, as they were called, were required of all the students as a part of the regular course.

Regular drawing exercises of five hours per week were held in the drawing room, during which time each student received personal instruction whenever it was required. In addition to this, recitations were held once a week in the class room and lectures given on the Theory of Drawing. As far as possible these exercises in theory were kept in advance of the work in the drawing room, in order that the students might progress with their drawing as rapidly as possible.

Seven examinations were held in Theory of Drawing during the year, including those of the Semi-Annual and Annual. At the former, three students were conditioned, and one failing to make up his condition was obliged to drop the subject at the middle of the second term. At the annual examinations none were conditioned, no one obtaining a lower mark than fifty per cent. The drawings of the students were also examined and marked at the Semi-Annual and Annual examinations. The following is the paper given at the Annual examination: —

ANNUAL EXAMINATION.

Theory of Drawing.

May, 1875.

1. Construct a diagonal scale of three inches to the foot, from which sixteenths of an inch can be taken.

2. On a given line construct a semi-oval, which shall pass through a given point on the bisecting perpendicular of the given line.

3. Construct the projections of a line two inches long, when it is oblique to both planes of projection.

4. Construct the projections of a vertical circle seen obliquely.

5. Find the intersection of a vertical cylinder with a horizontal one, whose axis is parallel to the ground line. Develop one of the cylinders showing the curve of intersection.

6. Find the shadow of a vertical cylinder resting on the horizontal plane, when it falls on both the horizontal and vertical planes of projections.

7. Find the shadow of the floor of a bridge upon the concave surface of a vertical abutment whose plan is shown on the blackboard.

8. Draw the isometric of a cross and pedestal. Also the isometric of a circle on the face of a cube.

9. Draw the isometric of a rectangular pyramid, and find its shadow. Show all construction lines used.

10. Construct by means of three planes, the perspective of a triangular pyramid and its shadow.

11. Construct by the method of diagonals and perpendiculars the perspective of a cross.

12. Find the perspective of a cube by the method of lines in parallel sets, or by vanishing points, and find the perspective of its shadow by the method of vanishing points.

Respectfully submitted,

H. N. MUDGE,

Instructor in Mechanical Drawing.

DEPARTMENT OF DESCRIPTIVE GEOMETRY, STEREOTOMY AND DRAWING.

To the President: —

The preparation of this third annual report has been a pleasure, as well as a duty, owing to the marked gain over previous years, particularly in the firmer establishment of wholesome traditions and usages. These traditions and usages, and the spirit of mutual ambition and co-operation in which work may be done, form, as hardly need be said, an unwritten law, more influential upon the quality and amount of work done, than formal rules and prescriptions can be, and one which has found a happy illustration in my work, generally, of the past year.

Being otherwise fully occupied, my personal attention to the *first year class*, during the first half year, was limited to a careful laying out of their work with the instructor, frequent conferences on its progress, and visits to their drawing room to aid and encourage their labors. During the second half, as in the previous year, I shared in the regular class and drawing room instruction, hearing each half of the class one half of the term.

The results of the year's work are on record, and well reward the labor spent by the faithful instructor in securing them. The subjects pursued were, as before, Elementary Drawing Operations, including Free-hand; Elementary Projections, and Perspective, with weekly lecture and interrogative exercises, and frequent drawing exercises.

The conducting of the *Second Year Class* through their Descriptive Geometry, during the first half year, was marked by the first use of my new text book on that subject, and by the lively zeal and diligence exhibited by the class in working out as full a programme as the time allowed.

The class had three exercises per week, each, in recitation and drawing, for five weeks, and then two per week for about ten weeks, giving, after loss by holidays and in the opening week, thirty actual class room exercises.

After long experience in teaching the subject, I am perfectly satisfied that at least thirty-six exercises, with ample time for study, are necessary for giving a fairly comprehensive course as a foundation for subsequent applications. And as this raises the question, What *is* a fairly complete standard course in Descriptive Geometry for our more advanced Technical Schools? I will add the following summary contribution towards a discussion of it.

For ten consecutive years, I had given a course whose composition and results were as follows, the number of problems varying from 100 to 109 for the ablest classes.

I. The Point Line and Plane; 21 problems.

II. Developable surfaces (including the developable helicoid) their tangent planes; intersections with planes, and with each other; and developments; 26 problems.

Auxiliary plane constructions upon conic sections, conveniently associated with the preceding; 8 problems.

III. Warped surfaces, representing seven of them, as illustrative of general properties, and for subsequent wants in Machine Drawing and Stone Cutting; 20 problems.

IV. Double curved surfaces, singly, and as usefully combined with each other, or with any of the preceding, either in intersections or tangencies; 19 problems.

Special curves; spiral, cycloidal, helical, for after use in Machine Construction and Drawing; 15 problems; 109 in all.

The aggregate results, taken from the original records, were as follows: Number of examinations in ten years, 20. Number

of students appeared, 565. Total number passed on first examinations, 460. Average per cent. of ditto., 81; yarying from 50 to 100 per cent., according to the quality of the class. And here it is well worthy of note, that in the last six of the twenty examinations, an average of 92 per cent., varying from 87 to 100 per cent. of all who appeared, passed. This was doubtless due, partly to higher standards of admission, strictly enforced, partly to improved details and means of instruction, and partly to generous class ambitions not to be outdone.

At our semi-annual examination, now, very properly, as I think, made final, in view of the strict intermediate examinations and other reviews, 42 men appeared, of whom 32, or 76 per cent. passed, on marks of 60 or above. Of 18, conditioned by failure or absence, four have since made up their conditions, four left, and the remaining five, partly on account of numerous other conditions, preferred to make a thorough review during the summer. The work required in the class room was seventy-one problems, in the thirty exercises.

Each student was *required* to draw at least *fourteen inked* figures, in behalf of fully finished practice. Forty-seven men, being all who presented drawings, submitted *twenty-two* inked figures each, on an average, besides an average of twenty-three pencilled figures each; the requirement being that each student should make as many of the latter as possible besides the inked ones.

It is important to add that all of the figures were required to be taken from the "examples" in the book, where the given parts were differently placed from those of the engraved plates, and that most of the inked figures were the larger ones, subsequent to those of the Point, Line, and Plane, and equivalent to from two to four times their number of the pencilled figures.

Turning over the "fifteen" problems, more or less, of "mechanical curves" to the department of Mechanical Engineering, the experience of the past year would doubtless enable a fair representative course of eighty problems to be given, with a high average percentage of success, provided that Descriptive

Geometry could be alternated with other subjects so as to give it three days per week, with the consequent continuity of study so peculiarly desirable when beginning it, during the first five weeks of the term.

Third Year's Class; Stone Cutting. The advance made in this subject towards a desirable standard has been nearly as great as that secured for the descriptive geometry. Occupying four hours per week of the first half year, I was personally present with the class in the drawing room through the whole of that time, and also at some extra hours.

I divided the term into three portions, to give pleasing and useful variety to the exercises. In the first five weeks, each student was required to work from the plaster models, making full working drawings of at least three of them. To provide agreeably for the voluntary element, each man was further, under due limitations, allowed to choose his own models. Some chose winding stairs, or others of like difficulty.

In the next seven weeks an elaborate form of wing-wall was given, embracing a front, partly plane, and partly conical, bed surfaces the same, and the top, with the coping, formed of a combination of mutually tangent warped surfaces, the whole designed as both a tolerably comprehensive review of Descriptive Geometry, and a practicable and handsome masonry structure. This, being a long continuous problem, suffered from the want of continuity in the study of it, coming as it did but twice a week, so that I had to supplement the printed notes of it which I had always found ample, when giving the work in eight consecutive days, by numerous written ones, posted from time to time, and amounting to a full text of the problem. In this way, all thoroughly worked up a task as extended and difficult as has often been spread over a whole term.

The remainder of the term was devoted to the groined arch, drawn twice, and on two different systems, by several. In the system drawn by all, the inner groins alone were straight as seen in plan. In the others, both the outer and inner groins were thus straight. Of the two methods by which the latter

unusual result can be brought about, the one chosen was the simpler, though practicable only within certain limits. In all cases full details were made.

Besides the work done with the First Year Class, and already mentioned, I gave a very satisfactory course in Shades and Shadows to the architectural students and to three others, volunteers, during the second half. An interesting special work in the same period was that with the "special architects," in elementary Masonry and Stone Cutting. Five inked working drawings being required, from five to eight were made, some of them elegantly, and including winding stairs, and other equivalent problems.

All of which is respectfully submitted,

S. EDWARD WARREN.

July 5th, 1875.

REPORT ON THE INSTRUCTION IN PHYSIOLOGY AND HYGIENE, AND ZOÖLOGY.

To the President: —

The lectures on Physiology and Hygiene, thirty in number, are given in the second half of the first year, when the students have acquired such a knowledge of chemistry as is necessary for the comprehension of the most important functions of life, such as digestion, respiration, secretion, and the processes of growth and decay. They are given thus early in the course, because the foundations of health or disease are very liable to be laid when young persons, freed more or less from the restraints and the care of home, associate together for purposes of intellectual and physical training; ignorance of the laws of life in youth may result in premature death or confirmed invalidism in the adult.

The course pursued is as follows: the organs of support, as the bones, ligaments, joints, muscles, and skin; the functions of nutrition, including digestion, absorption, circulation, respiration, and secretion: the function of the brain and nervous system; the laws of growth. Each of these departments has its dangers, and the student is instructed in the warnings given by the various organs that he may in time take measures of precaution. The dangers arising from the skin, the lungs, the muscles, the digestive apparatus; the use and abuse of physical exercise, the necessity of rest for muscles and brain, the importance of nourishing food and pure air, are specially dwelt upon.

The instruction is given by lectures, fully illustrated, and the students are advised to pursue the subjects in standard works suited for general instruction. It is believed that by the attention given to these important laws of life and health, the student may save himself from many painful and dangerous diseases, or, in case of sickness in himself or others, may assist nature in her attempts for his recovery.

The lectures on Zoölogy, also thirty in number, are given in the first half of the third year, based on the previous knowledge of human physiology, and are intended to present such a view of the principles of animal life as every educated person should have, and to serve as a basis for the subsequent lectures on Palæontology which is of such importance to the geologist and mining engineer and the student of natural science. Of course, in thirty lectures such a vast field can be only partially covered, and no attempt therefore is made to do more than to give the elements of the science, such as will display the distinguishing characters of the great classes and their principal sub-divisions, — show the gradual progress in time and development from the simplest protozoön to the highest mammal — and to indicate, as far as may be, the plan of creation, which is equally significant whether we regard it from the Darwinian or the Cuvierian point of view. The lectures are fully illustrated by diagrams belonging to the Rogers collection, and by specimens from the Boston Society of Natural History.

SAMUEL KNEELAND,
Professor of Zoölogy and Physiology.

REPORT UPON THE INSTRUCTION IN PHYSICAL GEOLOGY AND GEOGRAPHY.

President Runkle: —

Dear Sir: — As no report upon the instruction in this department has been presented before, it may be well, at this time, to briefly notice it from its beginning.

The work began four years ago, with a single course of instruction in Physical Geography and Physical Geology, given to the students of the second year. The plan adopted of teaching in the same course those portions of geographical and geological knowledge, which by nature are inseparably associated, has been the foundation of all the good results thus far obtained. Each examination of the class has furnished additional proof that the students acquire greater accuracy and more completeness in geographical knowledge, by considering the surface features of the earth as the outward expressions which the geological structures beneath them have received through the agencies of geological change. This association of these subjects is one which advancing science is daily rendering more indispensable in any well organized course of instruction in this department, and it is, therefore, one which the Institute should carefully perpetuate.

Although the first results of the instructions given were better than I had anticipated, yet the rearrangement of the different courses of study at the Institute and the introduction of

Political and Industrial Geography as a fourth year study, have made the present results far more satisfactory.

The classes in Physical Geography are so large, that it becomes almost necessary to give a large portion of the instruction by lectures. The students are required to take brief notes in the class and to carefully write them out in full at their rooms. Most of their note books have shown a logical arrangement of topics, a correctness in definition, a clearness in description and explanation, and a fullness of statement, which have been creditable to the students. The course has been so arranged as to give a general knowledge of the subject, rather than a minute one of its details, that it may be adapted to the students of the different courses, and that it may serve as a general introduction to the more specific branches of science.

The class in Political and Industrial Geography, being much smaller and composed of students of the fourth year, a somewhat different method in the instruction can be pursued to advantage. While lectures are given upon such topics as can be better presented by them than by other means now at our service, topics are also assigned, either to the class or to individual members, upon which they recite, giving such information as they may have obtained from authorized sources; and personal observations are sought as much as possible.

This course is designed to teach the association of the earth's productions with certain geographical features, geological structures and climatic conditions. The influences which these productions, together with the physical forces acting in the inhabited portions of the earth, exert in determining or modifying the characteristics of races, nations, habitations, modes of life, industries and civilizations of men, are made subjects of special consideration in this course.

The progress attained in each of these courses has been limited to the more careful arrangement and better presentation of the topics, and to the increasing interest which the students have shown in the work.

To make this department what it should be, room and apparatus are indispensable. The subjects taught are of such a nature that good representations are required for the proper presentation of them. Thus far, however, the illustrations have been those furnished by the instructor, there being no available room for the keeping of such materials. I hope the day may be hastened, when a proper room can be appropriated by this department, where the best maps of various kinds, charts, models and other illustrations, may be safely kept and used for this instruction. Until that time, the progress, if there be any, must be very slow, for the difficulties which now arise are more than the instructor can overcome. May we not even anticipate the day, when we shall have a geographical room so well appointed that it shall be to the geographer, what a museum of natural history is to the naturalist, a repository of such valuable materials and a centre of such instructions, as shall lead the more advanced student and the specialist to seek the opportunities offered.

Respectfully submitted,

W. H. NILES,

Professor of Physical Geology and Geography.

THE COURSE IN PALÆONTOLOGY.

To the President: —

The section of Palæontology and special Zoölogy has now a Laboratory which has been fitted up in the basement of the Museum of the Boston Society of Natural History. This room is commodious and is comfortably furnished with cases for the storage of an educational collection. The present collections of Palæontology available for class purposes are considerable and quite efficient, though by no means complete. Considerable additions however, are made every year by the Assistant, Mr. Crosby, as he works over and picks out the duplicates of the collections, which are being prepared for exhibition in the Museum of the Society. There are many forms absolutely indispensable to the system of instruction, which can only be attained by direct purchase and these should be obtained without too great delay. The system of instruction consists in completely illustrating all the more important points of any one lecture, either with specimens or with diagrams, or with both, if essential. Specimens are placed in the hands of the students during the lecture, and they are obliged to make sketches which shall show that they have seen the characteristics described from the rostrum. One would suppose that a very small amount of ground would be gone over in each lecture, and that the compensation for this would be found in the thoroughness with which the main points of the lecture could be comprehended. Such was my own impression until I found to my great surprise,

that the amount of ground covered in any one lesson, was almost equal to that which is usually condensed into an extemporaneous lecture, occupying the same length of time in its delivery. It is evident also, that constant effort for improvement will reduce this difference, and I hope to show that proper manipulation of specimens by the students themselves, not only materially assists them to understand the teacher, but is of great assistance to him in the abbreviation of his oral instructions or descriptions. Of course it will be understood that the system has been principally applied to those who have learned the elements of drawing, but I have had instances of men who knew almost nothing in this direction. Though these could not in any given time usually equal those who had had previous instruction, it was very astonishing to see how quickly they supplied the deficiencies of training, and learned to sketch more or less creditably. A knowledge of the art of delineation is therefore of great assistance in the practical application of this system, but the absence of this knowledge is not an insuperable obstacle, or at least has not yet been found to be so by the writer.

Though the lectures only occupy two hours per week for one term, and the Institute schedule does not allow any time for laboratory work in this department, that is, only about thirty hours in all, the students do get a certain reliable grounding in Structural Palæontology, certainly far more than could be obtained in the same time by the ordinary process.

The examinations are conducted upon a similar principle. There are about twenty questions intended to be answered in writing and covering the whole ground practically and theoretically, and a box containing about ten specimens which must be named, described and correctly referred to their separate divisions. The greater or less success of individuals proves how completely such a system is a thorough test of proficiency. I have known several inattentive and undeserving young men to pass the questions very creditably, but never yet has one been able to get through his allowance of specimens, where no special gifts of memory or intellect could supply the place of previ-

ous application. Again I have had one very curious case of a student, who had been very attentive and constantly in his place, but who entirely failed to pass the written part, though the first in his class in the determination of the specimens. Usually the best class of students stand high in both parts, but not infrequently, as in this case, high powers of observation may be possessed by a person with little or no verbal memory, and perhaps only a moderate share of reasoning power. I would most earnestly recommend that some steps be taken by which students may be obliged to spend a part of their time each week in laboratory work as supplementary to the lectures. This is absolutely necessary in order to fix in their minds the principal points treated of in the lectures. There is a certain rawness about the information obtained in the lectures and a certain amount of error which can only be overcome by greater familiarity with the specimens. The least time which ought to be given, would be an hour a week, and with this something might be done to cure this defect. Quite complete collections of the typical forms of animals are in course of preparation, and will be completed in the course of another year as far as it will be possible in the present laboratory. The collections belonging to the Institute, though stored in the building of the Society, are labelled so as to be readily identified, and so also are those belonging to the Society, the duplicates of whose collections are used to a limited extent for the benefit of students.

Of course it will be understood that in such a course as is here described no text books are used. There are most excellent books in existence, but all are either too extensive or simply stratigraphical in their arrangement.

The difficulties in the path of farther progress in this, lie in two directions. The students are at first but very slightly prepared in Zoology, so that they enter upon the course without a sufficient general knowledge of Natural History. This obliges the instructor in Structural Paleontology to make the course much more general than it should be, and forces him to dwell upon the general characteristics of the classes and orders of the

animal kingdom, when he should be dealing more particularly with smaller divisions. Then again, all the instruction in Zoölogy and Palæontology should be preparatory to a course of lectures and laboratory study in Stratigraphical Palæontology. This course is at present entirely deficient, and the student therefore to a great extent loses that which is most important to him, either as a mining engineer or geologist. Both of these courses should be made as long as possible, and should be accompanied by a proportionate amount of laboratory work. At present the amount of time given is wholly inadequate, and the students are necessarily left in ignorance of one of the most essential parts of his preparatory training as a mining engineer or practical geologist.

A. HYATT,
Professor of Palæontology.

REPORT OF THE DEPARTMENT OF GEOLOGY.

President Runkle:—

DEAR SIR:—The courses of instruction in Geology in the Institute of Technology are, as you are aware, in part general and in part special in their character. The relations of Geology to every-day life are such that a certain knowledge of it must now be considered as an indispensable part of higher education. The student of physics, of chemistry and of mineralogy finds in geology the application and the practical significance of these studies, while the student of physical and even of political geography learns how intimately these subjects are connected with the geological character of various regions. Hence it is wisely ordered that in the course of study at the Institute, a certain amount of instruction in geology shall be obligatory for all the students. This is given by a course of thirty lectures in the second half of the third year on Elementary Geology, embracing *first*, a discussion of the objects and the scope of geology and its relations to physical geography, chemistry, mineralogy, botany and zoölogy; *second*, the nature, origin, structure and arrangement of stratified rocks; *third*, the history of the successive rock-formations, their geographical distribution, their lithographical character and their organic remains; *fourth*, the theory of eruptive rocks and volcanoes, and the general principles of geological dynamics.

Of the students of the fourth year, those whose studies are such as to bring them more directly into relation with matters pertaining to geology, have a special course of forty lectures in the first half of the year. These lectures, which are obligatory for Mining Engineers, Metallurgists, Chemists and students in Science and Literature, are also followed by a good number of optional students, including physicists and specials. The subject of these lectures is nominally American Geology, but in its treatment occasion is taken to discuss many matters of general interest much more fully than in the elementary course. The crystalline rocks, both stratified and unstratified, are first considered, and in this connection particular attention is given to their mineralogy and to lithology. In tracing the history and the distribution of the various stratified rocks the principles of geological classification are considered with reference to the developments of geological science both in Europe and America, and the bearings of palæontology are illustrated. The relations between the various geological formations and the great physical features of the continent are discussed at length, and a general view is given of the mineral wealth of the country and of its distribution considered both geologically and mineralogically. These lectures are illustrated by maps, plans and blackboard sketches, and also by a large collection of rock-specimens, with which the students are made familiar. It is to be regretted that there cannot more time be given to the systematic study of these labelled and classified collections, but they are so arranged that students can at all times have access to them, a privilege of which many avail themselves.

In the second half of the fourth year the subject of American geology is farther considered in a course of twenty lectures on Economic Geology, designed especially for the students of Mining Engineering. In this course the ores of the principal metals, coal, petroleum, salt and all other useful minerals are made the subjects of discussion with relation to their geological and geographical distribution in the United States, the modes of their occurrence and their economic importance, the whole, as

before, being illustrated by large collections. The object of this course is to give the student a concise view of the mineral resources of the country.

This is followed by a course of ten lectures on Rocks and Minerals employed as Building Materials, designed for students in Architecture and in Civil Engineering, but attended also by the students in Mining Engineering, it being made to include a farther portion of economic geology. In these lectures the elements of mineralogy and lithology are discussed with especial reference to materials used in construction. Granites, limestones, marbles, sandstones, slates, mortars and cements, and clays for bricks and terra-cotta are here considered both with reference to their nature and mode of occurrence, the manner of working them and their distribution in the United States.

In addition to all these there is given to the students in the latter part of the fourth year, a course of ten lectures on Chemical Geology, in which are discussed the origin of the various rocks of the earth's crust, the formation of mineral veins, ore-deposits and mineral springs, and the nature and source of volcanic phenomena.

The number of students following the course of Elementary Geology last year was forty-five, of which forty-three passed the examination. Of the students of the fourth year, fourteen attended the course on American Geology, and eight the courses on Economic Geology and Chemical Geology, all of whom passed. Eighteen followed the lectures relating to Building Materials and of this number fourteen passed.

No special text-book is made use of in these courses of instruction, but the students are recommended to read Giekie's edition of Jukes's *Manual of Geology*, Dana's *Manual*, and Lyell's *Student's Manual of Geology*.

The general plan and scope of the studies in this department may be seen by the examination-papers for the past year, which are subjoined.

EXAMINATIONS IN GEOLOGY.

Elementary Geology. Third Year.

May, 1875.

I. State the differences between crystalline and uncrystalline stratified rocks, with illustrative examples.

II. Describe the nature, mode of occurrence and principal varieties of eruptive rocks.

III. Define bedding, lamination and slaty cleavage in rocks, and explain the origin of the latter.

IV. Give the great divisions of rocks with regard to life, and illustrate the law of progress in animal forms.

V. Give the history of coal, its origin and mode of occurrence.

VI. Explain the nature of anticlinals and synclinals, and their relations to erosion.

VII. Give the theory and mode of formation of salt-deposits.

VIII. Give the limits of the American paleozoic basin, and its history.

IX. Explain the origin of limestones, of sandstones and of clays.

X. Describe the three great classes of superficial or quarternary deposits.

American Geology. Fourth Year.

January, 1875.

I. What are the great divisions of the Eozoic rocks, and their characteristics?

II. Give an account of the mineralogy of the Laurentian limestones.

III. Give a list of the divisions of the New York system of rocks, and the lithological characters of each.

IV. Give an account of the paleozoic Carboniferous system of Pennsylvania, and of that west of the Mississippi.

V. State what mesozoic rocks are found in eastern North America, and what we know of their fauna and flora.

VI. What do you understand by palæontological, and what by stratigraphical breaks? Give examples of each from the American paleozoic.

VII. Give the history of the granites and of the mesozoic dolerites of New England.

VIII. Give the geological history of the North Mountain of Pennsylvania.

IX. Give an account of the coal-deposits of the Rocky Mountain region.

X. Explain the nature and origin of the drift-phenomena of New England.

Economic Geology. Fourth Year.

May, 1875.

I. Describe the iron ores of the eozoic rocks of the United States; their nature, composition, mode of occurrence and principal localities.

II. Give the history of the various paleozoic iron ores of the United States, with details as above.

III. Give the geological and mineralogical history of the native copper of Lake Superior.

IV. Describe the petroleum wells of Pennsylvania and of Canada, and their geological history.

V. Describe the anthracitic and semi-bituminous coals of the United States, and their geological relations.

VI. Describe the gold-deposits of eastern North America, their mode of occurrence and geological history.

Chemical Geology. Fourth Year.

May, 1875.

I. Give the classification of mineral springs, and the origin of the various classes of waters.

II. Explain the origin of limestones, of dolomites and of gypsum.

III. What is the theory of the formation of iron-ore deposits.

IV. Explain the theory of the origin of beds and of veins of metallic sulphurets.

V. State the three principal theories as to the origin of crystalline stratified rocks.

VI. Give the various theories of volcanic rocks, and the arguments for and against each.

Geology of Building Materials. Fourth Year.

May, 1875.

I. Explain the differences in texture and structure between crystalline and uncrystalline rocks.

II. Illustrate the porosity of rocks, its importance, and the mode of its determination.

III. Describe the bedding of rocks, its meaning and its importance to the builder.

IV. Explain the effect of heat on granites and on sandstones.

V. Describe the nature, character and varieties of marbles.

VI. Explain the structure, and give the characters of roofing-slate.

VII. Describe the differences between pure magnesian and hydraulic limes.

IX. Give an account of cements and asphaltic concretes.

X. Give a description of the clays used for bricks and for terra-cottas.

I may here be permitted to call attention to the straitened condition in which this, like so many other departments of the Institute, is now placed, and which greatly detracts from its efficiency. The single and indifferently lighted room, which now serves alike for lectures and for collections is not adequate for either of these purposes, and is moreover subject to be taken complete possession of, on occasions, for the purposes of the Society of Arts. From the limited accommodations of this room, it is found necessary to assemble the students of the third year in a larger lecture-room, the occupation of which at hours immediately preceding and following that assigned for Elementary Geology, does not permit either of the preparations or of the subsequent conferences, questionings and examinations of specimens which are found so advantageous in the other courses in Geology given to smaller classes in the room reserved for that purpose. A lecture-room sufficient for the larger classes, fitted not with chairs, but with desks at which notes can be conveniently taken, is greatly needed for the department. In addition to this there should be a reading-room with tables where

the students in geology might at all times find for consultation the various text-books, special treatises and state geological reports, the study of which should form a part of the work of the advanced students.

Moreover there is greatly needed for the Institute a proper Geological Museum in which collections should be suitably arranged for study, in glazed cases. The collections belonging to the department and my own large accumulations are, for the greater part, necessarily hidden away in boxes, and require for their utilization a large and well lighted room with table-cases, wall-cases and drawers, in which these precious materials for study can be properly displayed. Finally it is greatly to be desired that there should be some facilities for the study of the applications of the microscope and of chemistry to geology. Proper microscopes, collections of rock-sections and means of preparing sections of American rocks, are required, and with these a special laboratory for their farther chemical study. Outside of the Institute building Professor Hyatt has already been enabled to lay the foundations of a working laboratory for palæontology in the rooms of the Society of Natural History, and this in connection with the scheme I have above indicated would enable us, with adequate pecuniary means, to build up in Boston such a school for geological study as has hitherto been wanting in the country.

Respectfully submitted,

T. STERRY HUNT.

Boston, December, 1875.

BRIDGE AND ROOF CONSTRUCTION.

President Runkle: —

Dear Sir: — In accordance with your suggestion, we have endeavored to supplement the established course in the department of Civil Engineering with a parallel course of lectures and exercises on Construction.

The experiment has proved entirely successful, and we are able already to see the favorable results of an immediate application to practice of principles derived from theoretical investigation.

In previous years, the time of the students has been so fully occupied with other studies that there was no opportunity to introduce a course of this kind; but with the gain recently made in the time of completing various subjects of study, we are able now to begin with the second half of the third year, the lectures, experiments and excursions which I am about to describe.

After careful consideration and experiment, it has seemed best to adopt an analytic, rather than the usual synthetic method of instruction. First of all, the students are to get a general idea of the structures that they are afterwards to study carefully in detail, and finally to design for themselves. For this purpose, we have made class-excursions, and have examined bridges in this vicinity, noting the prominent features in each form of construction. Then in subsequent lectures, I have shown them the principles that led to the adoption of these

forms in each case; — in short, the students have been shown *why* the bridges were constructed in the manner we found them. Structures similar to those examined are also described, and modifications and improvements suggested.

In this way, the interest of the student is awakened and constantly maintained. He has always a clear idea of the subject under discussion, and is better able to undertake, later in the course, the investigation of the magnitude of stresses in structures with which he has, in this way, been made already familiar.

For example, taking the form of bridge known as the Howe-truss, we observe the manner in which the bridge is built, noting the form and material and method of combining and securing the various parts. In the lecture-room, the first point to bring out is, that in certain localities where wood is cheaper than iron, this form of construction is preferable on the score of economy. Then we demonstrate that the braces must be mainly struts, since wood is better able to resist compression than tension. Flexible models of trusses are also exhibited, showing how the effect of a weight in the centre is transmitted to the abutments through the braces; and we have then three important principles of construction demonstrated and illustrated in this one form of truss, — first, the reason for using wood instead of iron in any particular case; second, the importance of employing it, so far as possible, in the form of compression members; and, third, the purpose of inclining the main braces upwards towards the center of the bridge.

This explains the distinctive features of the Howe-truss, and, since we are not to investigate the actual magnitude of the stresses, it remains only to discover from what simple or elementary form of truss this was derived. Working backwards, we reduce the number of main braces to two, finding the ordinary trapezoidal or queen-post truss, and simplifying still farther, we come at last to a plain beam extending over an opening, with bracket braces running up to it from the abutment below,— a bridge with no lower chord.

This example serves to illustrate sufficiently the general method adopted in explaining the principles of bridge construction, and the designing and building of roofs. In every case where it was possible we have employed models illustrating the form of structure under discussion, and by means of flexible members in miniature, have been able to observe the effect of loads variously applied and distributed. In cases where the structures were too complex to be readily copied in models, we have had recourse to diagrams, photographs and drawings, illustrating some of the best engineering works in this country and in Europe. Many of these works I have visited myself, both at home and abroad, for the purpose of careful inspection and study; and the sketches and measurements obtained in this way have been of great service in illustrating the lectures on Construction.

In no case has it been considered enough to give a mere description of a structure without reference to general and particular principles involved in its design and execution. Each example has been studied and fully discussed in plan and detail, the object being to ascertain the considerations that led to the adoption of particular forms and combinations by the builder, and from these are derived precepts and principles to be applied by the student in other cases.

Reference to the accompanying *resumé* will show that the examples given and discussed have been comprehensive and numerous, so that the student, by this means, must become familiar with existing structures, representing the best designs of eminent engineers, and, in consequence, he has at his command a variety of forms and combination of parts, from which he can choose later in the course, when he is required to design bridges and roofs for himself.

I will add a synopsis of the subjects treated in the lectures given to the third year class.

First Lecture. Various forms of bridges shown by diagrams, briefly explained and the names learned.

The Howe-truss, Pratt-truss, Jones-truss, Whipple-truss, Post-truss, Fink-truss, Boilman-truss, Warren-girder, Lattice and Trellis-girders, Long's-truss, Burr's-truss, Bowstring-girders, Double Parabolic trusses, Hogbacked girders, Pauli-truss, Sedley's cantilever bridge, Continuous girders, Arches, Suspension bridges, Von Ruppert's bridge. — Main characteristics of each form.

Second Lecture. The same forms reviewed and more fully explained. References given of particular examples to be seen of each type. The Howe-truss analyzed and discussed. The elementary forms of trusses from which this originated.

Third Lecture. The Pratt-truss compared with the Howe-truss and similarly treated. Relative merits of each, and prominent defects of both. Elementary forms found as before. From what has been already learned, we deduce the rule for the position of struts and ties as inclined braces, and show by models how each part acts when the model-truss is weighted.

Fourth Lecture. Incomplete structures. How missing members are to be supplied. Abstract of portions of Bow's Lectures on Bracing. Subject of counterbraces investigated.

Fifth Lecture. General and particular defects pertaining to wooden bridges. Iron introduced in combination with wood to remedy these defects. Relative economy of the two methods of construction. Examples of each.

Sixth Lecture. Iron-bridges. Reasons for not employing iron in construction more generally. Recent increase in the number of iron-bridges. Durability and elegance of these structures. Coincidence of theory and practice in designing and building. Results to be derived from the forthcoming report of U. S. Commissioners appointed to test iron and steel.

Seventh Lecture. Iron-bridges continued. Saving in wages of watchmen compared with the interest on cost of rebuilding wooden bridges with iron. Ordinary forms, — I. Cast-iron alone. II. Cast and Wrought-iron combined. III. Wrought-iron alone. IV. Wire-bridges; — general features and characteristics of each.

Eighth Lecture. Cast-iron bridges. Cases in which this material may be profitably employed. Its inferiority to wrought-iron in certain respects and its superiority in others. From this, the arch is found to be a suitable form of construction. Advantages and disadvantages of arches.

Ninth Lecture. Other properties valuable in cast-iron. Durability and facility of taking certain shapes. Figures given in regard to cost of working. Recorded failures of cast-iron bridges. Government prohibition against their erection.

Tenth Lecture. Highway bridges. Most simple form. Result of Hodgkinson's experiments. Opinions of other eminent engineers in regard to ultimate strength. Most economical shape of girder. Girders with parallel flanges — how tested for safety.

Eleventh Lecture. Cast-iron continued. Examples of short-span bridges. I. Simple cattle-pass. II. Nottingham Bridge,— five spans of thirty-five feet each. III. Bridge over the Midland Railway,— one span of thirty-five and one half feet.

Twelfth Lecture. Standish Bridge,— eighty-three and one third feet span. Ten cast-iron half arches forming the roadway — how cast and why. Peculiarities of connections. Full details of construction, with an account of the unusual manner in which the bridge was designed by Barlow.

Thirteenth Lecture. Long spans. Rochester Bridge, by Sir William Cubitt,— one hundred and seventy-eight feet span. How constructed as to casting and connections. Deflection. Quantity of cast and wrought-iron in the whole bridge. Southwark Bridge over the Thames. Report on its resistance to decay since 1819. Nature and amount of the traffic over this bridge.

Fourteenth Lecture. Wrought-iron Bridges. Extraordinary length of spans which have been made of this material. Ratio of depth of girder to length in single and continuous girders. How this ratio is determined. Local conditions affecting the design in certain cases.

Fifteenth Lecture. Usual forms of chord-sections. Objections raised by Calcott Reilly to these forms. His proposed section for chords. Struts and ties,— ordinary forms of each, and manner of connecting with the chords.

At this point, the lectures were interrupted by the annual examinations. It was my intention to have proceeded farther with a detailed description of the bridges in and about London, together with an historical account of these structures, beginning with the building of the Old London Bridge in 994, by the Brothers of St. Mary's Monastery. During the coming

year, the course will be so laid out as to cover a wider range of subjects.

It will be observed that no mathematical investigations are undertaken in this scheme. The nature of the stresses is determined in the structures under consideration entirely by observation of flexible models, so arranged as to show thrusts and pulls in the different parts. This method gives the student a much clearer idea of the subject than can be obtained from mathematical study alone, and places him on a broad and sure foundation for the pursuit of advanced theoretical investigation during the last year of his professional course of study at the Institute.

If the objection be brought that a portion of the instruction is quite elementary in its character, my reply is, that in no other part of our course is provision made for instruction on the subjects I have taken up and presented in this way. Professor Rankine's work, the only text-book at present used on the subject of civil engineering, with the exception of the Field Book, fails to give information on most of the topics treated in this course; and, if left to himself, the student is not likely to acquire a substantial and thorough knowledge on these points by independent reading.

FOURTH YEAR COURSE IN DESIGNING.

Want of time and a lack of preparation were serious obstacles in the way of the graduating class of 1875, during the three months in which they attempted the work of designing structures. It was then that the want of previous preparation by means of a course on Construction during the third year was most keenly felt and regretted, and the labor of students and teacher was greatly increased thereby. In spite of all difficulties, however, some very creditable designs of bridges and roofs, carefully worked out and intelligently planned, were presented at the close of the term.

The present graduating class, at the commencement of their fourth year, have already begun the subject of Designing, and

are, in this respect, nearly four months in advance of other classes.

It is my intention to make this course, during the coming year, much more thorough and comprehensive than before, by giving a greater number and variety of problems to be worked out in the form of designs for bridges, roofs, foundations, etc., such as engineers in the practice of their profession are continually called upon to plan and build.

Thanking you for the personal support and encouragement given me in this work, I am

Very Respectfully Yours,

WILLIAM E. HOYT.

THEORETICAL AND APPLIED MECHANICS.

President J. D. Runkle:—

DEAR SIR:—Until this last school year the Department of Mechanics was unable to derive material benefit from the change made in the courses of instruction a year and a half ago.

The opportunity having presented itself, however, was at once seized to extend the course and to adapt it more fully to the needs of the purely professional departments. The subjects treated were not only those formerly pursued, viz., the Composition and Resolution of Forces, the Conditions of Equilibrium, the subject of Distributed Forces as applied to determinations of centres of gravity and the laws governing the internal stress of bodies; and the main laws of Dynamics, viz., those governing motion, momentum, force, energy and allied subjects as Moments of Inertia, Radii of Gyration, etc., etc., but the course was made to include the ordinary theories of the Strength of Materials as applied to tensile, compressive, transverse, and torsional tenacity; the laws of Deflection of beams and columns, determinations of the stress in granular masses, the method of ascertaining the stresses in Frames, etc., etc.; the formulæ applicable to each of the above cases were deduced and studied, and an attempt was made to devote (as far as possible) special attention, in the case of each student, to the different subjects, according to their relative importance in his professional course. The text books used were the same as hereto-

fore, viz., "Rankine's Applied Mechanics" and my "Notes on Mechanics."

The progress of the class was quite satisfactory, those who were conditioned having subsequently made up their conditions at a re-examination.

The extension of the course above alluded to, without any increase of the time allotted to the subject, has been rendered possible by the fact, that the Calculus is now completed before the Mechanics begins, instead of their being studied contemporaneously as formerly.

It follows that the attention of the student is more fully concentrated on his Mechanics, and also that he is not hindered in his progress through ignorance of the methods of the Calculus which he needs to use.

The changes made in the courses of instruction, together with the subsequent amendments and developments have exerted a very beneficial influence in all the departments, and, among other things, have rendered it essential that the students should acquire in their Mechanics a knowledge of all the theories which depend upon Mechanical laws, that find application in their professional work; and be thus enabled to apply that knowledge readily to the practical cases that may there arise. It is important also that the above should be completed by the end of the third year, so that in the fourth year when the student ought to be wholly devoted to his professional work, he may not be hindered by being obliged first to learn something that he should have had in his Applied Mechanics.

To accomplish this most desirable result, and to adapt its instruction to the special needs of the student in the course he has selected, the Department of Mechanics is doing and will continue to do its utmost; bnt it is evident that in order to obtain a satisfactory result the time now allotted to this subject, viz., three times per week for three-fourths of the third year, is not at all sufficient, this being no more than the time allowed when the instruction was confined to the main principles of Analytic Mechanics.

A number of subjects that should be studied in the Mechanics must now be omitted for want of time. Nevertheless, far more has been done this last year than heretofore, and more yet will be done as soon as the time is allowed; and it is hoped that at no distant day the Professional Departments may find that their students do acquire in their Mechanics those principles, theories, and formulæ which they need to apply in their own work.

Whenever it is found possible to complete the Calculus in the second year and devote three exercises per week to the Mechanics for the whole third year, a step will be taken which will decidedly assist in carrying out the above scheme.

I would also take this opportunity to repeat the suggestion I made to you last year, that in all cases where it is possible for a Professional Department to give to its students the practical applications of the theory immediately after or contemporaneously with their work on the same subject in Mechanics, it is certain that the students' interest will be increased and their progress hastened, both in their theory and practice, as has been shown in a very marked manner in those cases where it has been done. The instruction, as heretofore, is given by lectures, recitations and blackboard exercises, and the computation of numerical and practical examples.

In regard to the special courses given in this department to the students of Mechanical Engineering during the last year, I will state that the subjects studied were as follows:

Fourth year's class — Water Power — Strength of Materials — Link and Valve motions and Thermodynamics.

Third year's class — Strength of Materials — Link and Valve motions and Mechanism.

Second year's class — Mechanism.

The text books used were Professor Rankine's treatises on "Machinery and Millwork" and on the "Steam Engine and other Prime Movers"; Weisbach's Mechanics of Engineering, Maxwell's Theory of Heat, Anderson's Strength of Materials,

Auchincloss' Link and Valve motions, Willis' Mechanism, Goodeve's Mechanism, and Shelley's Workshop Appliances.

The progress of all the classes was very satisfactory, and it is especially the good results derived from the fact that the same subjects are treated contemporaneously from different points of view in these courses, and in the Practical, the Graphical, the Experimental, and the Excursional courses of the Mechanical Engineering Department, that causes me to urge the suggestion made above.

Very Respectfully,

GAETANO LANZA,

Professor of Theoretical and Applied Mechanics.

DEPARTMENT OF MECHANICAL ENGINEERING.

President Runkle:—

Dear Sir:—No important change has been made in the system of conducting the Mechanical Engineering Department during the past year. The system of study by subjects has increased the number of text-books used. Rankine's "Machinery and Mill Work," Willis's "Mechanism," Shelley's "Work Shop Appliances," Anderson's "Strength of Materials," Goodeve's "Mechanism," Weisbach's "Mechanics," Rankine's "Steam Engine," Wilson's "Treatise on Steam Boilers," Maxwell's "Theory of Heat," Porter's and Richard's "Steam Engine Indicator," Auchincloss's "Link and Valve Motion," Zeuner's "Treatise on Valve-Gear," Francis on Cast Iron Pillars, and Francis' "Lowell Hydraulic Experiments" are used, with other text-books.

Our library has proved to be of great service, and we have occasion to thank heartily many gentlemen for special reports upon special subjects, and for letters containing valuable advice and information. Numerous manufacturing companies and firms have admitted us to their manufactories from week to week, and explained to us with great courtesy and patience the interesting operations which they were conducting, allowing us to return again and again to complete our notes of those operations in minute detail. They have also loaned to us many valuable working drawings, which our students have reproduced and

returned. I am satisfied that some important improvements in our manner of sketching and drawing have been introduced during the year.

Our Mechanical Laboratory has more than justified the expectations had of it, and I do not hesitate to express my belief that the young men who graduated from the department last year have had more actual practice in the use of instruments for testing steam machinery than many experts have had in a term of years.

I take advantage of the late date at which this report is issued, to say, that at the recent test of the Providence Steam Engine Company's Pumping Engine at Hope Station, Providence, seventeen of the students were invited to assist in the test, on account of the experience which they had had in our laboratory. Their careful attention to minute matters of observation, their accuracy, and their endurance of the fatiguing duties of the extended trial, were alike noticeable and praiseworthy.

Respectfully yours,

CHANNING WHITAKER,

Professor of Mechanical Engineering.

DEPARTMENT OF CHEMISTRY.

To the President:—

In the Laboratories for Quantitative Analysis there has been, during the past year, a large and enthusiastic class. The quality of the work done has, as a rule, been good; the amount large, the number of quantitative determinations that have been made averaging more than one hundred per week.

Considerable attention has been given to the analysis of ores and furnace products, and an important part of the work done by the students of Metallurgy, and of Mining-Engineering, during their senior year, consists of the analysis of ores employed in, and products resulting from, experiments performed in the metallurgical laboratory. Such analyses test the quality of the work performed, and will guide future experiments.

There has been a great lack of substances for analysis, the composition of which should be accurately known to those having charge of the instruction. A careful selection of substances, the analysis of which would give an appropriate analytical training for any branch of chemistry, has now been made; several samples of each substance have been collected, and prepared for analysis; a large number of these have been accurately analysed by the instructors in this department; and at present we have a fine working collection, the value of which, perhaps, only a teacher of analytical chemistry can appreciate.

The laboratories, though crowded, and quite insufficient for the present wants of the department, have been put in thorough repair, and have been much improved in minor details. Additional balances have been provided; the jet-aspirators of Professor Richards (Am. Journ., Dec., 1874) have been substituted for the "Bunsen" pumps hitherto employed for filtration and a modification of the same device is employed to furnish air for the blast lamps; increased facilities have been provided for volumetric, and for organic analysis, and for the analysis of copper ores and alloys by electro-deposition. To supply the want of a room for optical work connected with chemistry, a nook, in the metallurgical laboratory, kindly granted to the chemical department, has been furnished with a large reflecting goniometer, by "Meyerstein"; an optical circle, arranged for Landoldt's optical analysis, and also for use as a goniometer or as a spectrometer, by "Meyerstein"; a spectrometer, by "Browning"; a large direct-vision spectroscope, by "Zeiss"; a large inverted microscope, by "Tolles"; a smaller microscope, by "Tolles"; three dissecting microscopes, by "Zeiss" and others; a saccharimeter, by "Soleil"; with the minor appliances for chemico-optical work. But as these fine instruments are crowded into a room less than ten feet square, in which not more than two students can work at a time, they are much less useful than they otherwise would be.

The instruction in chemistry is much hampered by the want of a laboratory for qualitative analysis, apart from the laboratory which is used for the instruction in general chemistry; of a laboratory for organic chemistry; of a laboratory for applied chemistry; of a suitable reading room, where the books of the chemical library may be consulted, and writing done; of a number of small rooms, for the use of special apparatus. There is no room in the present building to meet any of these wants, and till some provision be made, further growth and development seem impossible. Every inch of room at the disposal of the department has been fully utilized, and the writer is at present utterly at a loss to know where to find place for a piece of

apparatus requiring but about four square feet of floor room. Even the private laboratory of the professors has been given up for the use of the students.

In consideration of the above, and of the yearly increasing number of students, and referring to the reports of the preceding year, made by the several professors of chemistry, the department would pray that relief, in some form, be afforded.

In conclusion I wish to add, that much praise is due the students; for their zeal, their sympathy, and their hearty coöperation, have done much to aid in the development of the department.

Respectfully submitted,

CHARLES HALLET WING.

Note: — Since the above was written, the laboratory for fourth year students, and the balance room, have been destroyed by fire; all the balances, and the collection of substances for analysis, above referred to, were destroyed, and the chemical library very seriously damaged. The books can, with a very few exceptions, be replaced, but it will require at least two years to restore the collection. We are indebted to Professor Cooke of Harvard University, and to Mr. Henry F. Durant of Wellesley College, for the loan of balances for immediate use; and to Cornell University for a collection of analysed substances sufficient for use during the present year.

For the present the fourth year students occupy places in the third year laboratory and in the private room of the professors.

It is expected that the laboratory will be restored and equipped for work by the first of January next.

THE COURSE IN MINING ENGINEERING.

To the President: —

It may be of interest at first to take a short but comprehensive view of the more strictly professional studies in this course, to ascertain the amount of symmetry in their arrangement, and also the advancement that a student is able to make in them.

The student begins his experimental work on entering the school with a course of general experimental chemistry, accompanied by a course of lectures. He then takes up qualitative analysis which is followed by a course in practical mineralogy.

At the opening of the third year he begins quantitative analysis, spending a large share of his time in the laboratory, receives instruction in palæontology, and attends lectures on mining throughout the year, and on geology the last half of the year. The summer vacation, at the close of this year, usually gives him an opportunity for an excursion to mining districts where he can have a chance not only to apply what he has learned, but to settle his mind on many vexed questions.

In his fourth year the student takes up assaying, continues quantitative analysis and geology; lectures on Metallurgy and ore-dressing taking the place of those on Mining of the third year. In the last half of the fourth year his time is mainly devoted to practical work on ore-dressing and smelting, which is at every step checked and controlled by chemical analysis and assaying. The subject for a thesis is taken from the work in the Mining or Metallurgical laboratory, or from works visited during the summer. Classes which have not had the privilege of making an excursion to mining regions during

the third year vacation, will have an opportunity to do so immediately after graduating.

Collateral subjects, and such studies as are calculated to give the student a liberal education, are carried on during the whole of the above course as far as is practicable. The subjects which come directly under the charge of the mining professor are given below in detail.

Instruction in Mineralogy. The subject is taught as far as possible in an experimental way.

Blowpipe analysis is dwelt upon sufficiently to enable the student to detect the common elements. A few specimens are then handled so as to gain a familiarity with, and quickness in recognizing, the physical features common to many minerals, viz., hardness, streak, lustre, diaphaneity, cleavage, etc.

Crystallography is taken up and studied until the class can recognize the crystalline form of the models and also of the minerals of the simpler forms.

Determinative mineralogy is begun at the same time with crystallography. Each student receives fragments of minerals, and determines the name of the species of each from its lustre, fusibility, and special features and reactions as put down in the excellent tables in Professor Brush's recent work on this subject.

The class is now well prepared to handle minerals with a view to become acquainted with the peculiar features of each by inspection with the eye alone. To this end four different reviews are made of the more important species.

A tabular statement showing the contemporaneous order of exercises is here given:

	1st hour of Exercise.	*2d hour of Exercise.*
5 Exercises	Blowpipe reactions.	Blowpipe reactions.
2 "	Physical features.	Physical features.
10 "	Crystallography.	Determinative Mineralogy from unknown fragments.
10 "	1st review of Minerals	"
6 "	2d " " "	"
4 "	3d " " "	"
4 "	4th " " "	"

The Instruction in Mining Engineering consists in a review of the machines, methods and processes, by which the various useful minerals are extracted from the ground and are made ready for the market or the smelter.

Veins, beds and superficial deposits are defined, and the methods of prospecting, boring and searching for them enumerated.

The various tools are mentioned; pick and shovel, schlegel and eisen, hammer and drill, drilling machines, powders, nitro-glycerine, fire-setting.

The methods of getting at and working out the mineral; shafts, levels, adits, stopes, wide veins, pillar and stall, longwall, square work, sumps, timbering, walling, dams.

Ore transportation on the level, on the shaft, engines, drums, ropes, cages, back balances, inclines.

Man transportation, ladders, rope hoisting, man engines.

Ventilation, bad airs and their causes, natural ventilation, furnace ventilation, machines, compression, distribution and regulation of currents, lighting, breathing apparatus, machines for testing badness of air, mine on fire.

Pumping, damming, checking, draining, Beam pump, Bull pump, steam pump, other devices.

Surveying a mine, transit, chain, tape, lights, targets, German gradbogen, clinometer, measuring by long wire.

Government of mines, financial, business consideration, causes of failure, mining law and the relations of Government to mines.

The students take notes of all the above subjects and illustrate them with careful pen sketches.

Instruction in Assaying. Each student has twelve or fifteen exercises at the assaying furnaces, learning to assay ores of silver, gold, lead, iron, tin and sometimes of copper and antimony. In these he has the opportunity of learning how to manage a simple fire, and the management of different fuels, coke, anthracite, Cumberland coal and charcoal.

Instruction in Ore Dressing and Smelting. The student is now fully prepared to begin practical work upon the extraction of metals from their ores. He receives an ore just as it comes from the mine and is expected to extract the metal from it in marketable form.

The experimental work of the laboratory is carried on by the students under the immediate supervision of an instructor, a sufficiently large quantity of ore being assigned to the student (from one hundred pounds to a ton) according to the quantity on hand and to the work proposed to be done. He first examines it for its component minerals, sorts and samples it, determines its character by analysis, from which he obtains the mineral percentage composition, and its value by assays. He also makes such other preliminary examinations as may serve to indicate the proper method of treatment. He then treats the given quantity, testing all his products at each step of the process.

These tests may be of two kinds:—(*a*) Commercial, in which case he assays all his rich and waste products alone for the metal under consideration, and thereby ascertains the percentage of metal saved in the rich products and that thrown away in the poor refuse products. He can tell at any time whether a rich product has been concentrated up to his smelting standard and whether a poor product has been sufficiently robbed of its metal to admit of its being thrown away. (*b*) He may make scientific tests of the machines and furnaces. Knowing the percentage of minerals in the ore started with, he may watch these minerals all through a complicated system of ore dressing by determining the principal mineral constituents of each product. After such a study he will have very good grounds for conjecture as to the efficiency of his machines for any other ore. In the case of a furnace his scientific tests will seek to find the chemical composition of all the ingredients that are put in the furnace and also of the slags, matts and metal which come out of the furnace. The tests will enable him to regulate the ingredients fed to the furnace so as to produce the slag which shall

have the least inclination to absorb and waste the metal, and which shall not badly attack the firebricks of which the furnace is made, and finally which shall run well or hold its liquidity for a sufficiently long time to effect good separations between metal and slag.

The mining machinery in this laboratory is supplied with power from an upright tubular boiler, which is fed with hot water by a force-pump and steam water-heater, by a ten horse-power engine. There are two suites of milling apparatus: —

I. A small five-stamp battery, capacity 100 lbs. of quartz per hour, of the form in use in Colorado and on the Pacific coast, an amalgamated plate, an amalgamating pan, a settler and concentrator of the kind used in the Washoe process in California and Nevada, for the treatment of silver and gold ores.

II. A Blake crusher with jaw opening 2 × 5 inches, crushing rolls, capacity 400 lbs. per hour, with automatic screens, a series of sorting V-boxes (German spitzlutte), two automatic machine jiggers, a Rittinger shaking-table, a Freiberg shaking-table, and a set of little finishing V-boxes.

These machines are all arranged to give up their overflow sand into hand buckets, and the overflow water into a large tank. The water from this tank is forced back into the feed tank and used over again. This arrangement makes it possible to perform an experiment without the loss of slime due to an overflow of waste water. Steam drying tables are at hand to dry the wet sand for the furnace. The laboratory also contains the following auxiliary apparatus: — a Whelpley and Storer pulverizer, an edge-stone mill, a Sturtevant blower, and Batchelder's dynamometer. The metallurgical laboratory contains a blast furnace, a reverberatory smelting furnace, a roasting furnace, a furnace for cupellation, furnaces for fusion, crucible and muffle assay furnaces, a blacksmith's forge, and a melting kettle.

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METALLURGICAL LABORATORY.

METALLURGICAL LABORATORY.

calities on this continent. These ores are worked, and reports sent to those who contributed them; and it is hoped that by such coöperation the laboratory will continue to receive the necessary amount and variety of ores.

The Course in Metallurgy. During the second year the studies of the courses in Mining Engineering and Metallurgy are the same, except that the mathematical studies in Mining Engineering are replaced by chemistry, in Metallurgy. In the third year the lectures on mining and applied mechanics given to students in Mining Engineering, are replaced in Metallurgy mainly by quantitative and industrial chemistry. With these exceptions the courses are the same during the four years, and although what precedes relates more particularly to the course in Mining Engineering, it will readily be understood to what extent it also includes the course in Metallurgy.

MINING EXPEDITION TO NOVA SCOTIA.

A party of ten students with two of the professors left Boston, by the St. John steamer, on Monday, June 7th, and spent three weeks in visiting some of the mines and mineral localities of New Brunswick, Nova Scotia, and Maine.

Arriving on Wednesday, at Dorchester, N. B., we crossed the four mile ferry, at high tide, to Hopewell, and succeeded, at a late hour, in obtaining conveyance to the Hillsborough Albertite mine. Here occurs that peculiar bituminous mineral whose origin and classification has caused so much dispute among geologists. The highly inclined strata are mostly of a soft, shaly character, and the difficulty of locating the shaft of a mine in such yielding materials is well illustrated by the experience of the miners. The present working shaft, though at the distance of two hundred feet from the vein itself, is found to have been moved a little already by the comparatively quick filling in of the worked out parts, while three different shafts

have before been abandoned on account of this unavoidable creeping. As the Albertite is highly prized as a means of enriching coal gas, it is desirable to send it to market in a state of purity. It is therefore, carefully washed at the mine in long sluices to free it from a slight accidental contamination of pyrites and shale. The stoping of this very brittle mineral is effected with less labor than that of any other substance procured by mining. At times no tool is needed to dislodge it, but the fragile solid breaks up of itself when a barrier is removed, and flows out with an inconvenient rush. Mr. Wm. Blacker, the agent, and Mr. Byers, the mining engineer, were very kind in their attentions, giving us full opportunity to see all that our between tides visit would allow, and fully explaining the nature and working of the mine.

We left the railroad again at Maccan and went by stage to the Goggins. At the Goggins mine a seam of coal about five feet thick and inclined at an angle of about 35° is worked very systematically by "back balances." The pillar and stall method is carried out in such a way that the roof is allowed to fall in, after almost all the coal in each panel has been hoisted to the surface. The strata among which the coal occurs are wonderfully rich in large and well preserved fossils. The high, precipitious bluff, extending many miles along the shore of the Bay of Fundy, shows a complete section of the tilted coal measures several thousand feet thick. There is here a chance to study every leaf of a huge geological book. The special features of this region were carefully explained to us by Mr. B. B. Barnhill, a former student of our Institute.

Going on to Londonderry we spent a day at the Acadia Iron Works and the mine two miles distant. The whole property is now owned by the Canada Steel Co., Limited. The iron belt extends some thirty miles east and west in the Cobequid range. The ore is chiefly limonite, occurring promiscuously, mixed with ankerite and siderite, in irregular veins and pockets nearly vertical. The limonite, which is in various states of aggregation, is probably the result of the slow oxidation and hydration

of ankerite, a double carbonate of iron and magnesium. The Company has in operation a charcoal blast furnace, and is intending to build a high furnace for coke. Large preparations are also in progress for the manufacture of wrought iron and steel by the Siemen's direct process. The coarse ore from the mine is reserved for the blast furnace, while the fine, which has heretofore been rejected as useless, is sifted to free it from dirt and then forms an excellent material to supply the Siemen's furnace. In the new process, the rejected slack of the coal mines is mixed with this fine ore to effect the reduction. So from two refuse materials the Company expect to make iron and steel of good quality; and at the time of our visit, some excellent wrought iron had already been made in this way.

The Pictou coal region was next in order. The coals are mined near Stellarton and mostly taken by railway eight or ten miles to the port of Pictou for shipment.

The principal mines are the Albion, Acadia, Vale, Black Diamond, and Drummond; the latter noted for the fire which occurred in it in 1872.

The Albion mine is worked upon a vein 89 feet thick by the pillar and stall method, with back balances 150 yards apart. These workings, however, only remove the upper nine feet of coal, and they rest upon a two feet seam of slate. The remaining 28 feet of coal is left for future working.

The Ford shaft is 980 feet deep and has a hoisting engine of 75 horse power and two large cages, one of which goes up while the other goes down. The men are all lowered into and hoisted out of the mine by means of these cages. Each cage has two platforms and accommodates 20 men, and makes the descent in 70 seconds. The engine lifts 4,800 pounds of coal at once and makes the trip of 980 feet in 45 seconds. The water is pumped from the mine by an upright engine of 260 horse power, which raises 95 gallons at a stroke and makes seven strokes per minute. The mine is ventilated by a large suction rotary fan wheel 30 feet in diameter, 10 feet wide, run

at 45 revolutions per minute in dog-day weather when the mine is hard to ventilate. This rate is equivalent to 90,000 cubic feet of air drawn per minute, which is the amount required by 20 horses, 200 men, and for the removal of the fire damp. The Superintendent, Mr. Hudson, very kindly extended to the party the privileges of the mine, and his son devoted his time to us in the exploration of this mine and the Cage pit, which is worked by the same Company.

In the Ford pit we had the uncommon experience of walking about underground, several miles, through dry, spacious levels, by the dim light of safety lamps, each of the party carrying one.

At Gay's River, seven miles from Schubenacadie, on the Intercolonial Railroad, is a very peculiar deposit, carrying gold. It is a conglomerate which has been pronounced by geologists to be as old as the carboniferous era, and as sedimentary deposits carrying gold are usually supposed to have derived that metal from the rocks from which their own pebbles came, this deposit gives a hint to the geologist that the veins originally carrying gold are pre-carboniferous. This ore yields from four to six dollars a ton, crushed by stamps and run over amalgamated copper plates.

The fourth of July was passed in Halifax, each one spending the day according to his own pleasure. A part of us went to several spots of much geological interest under the guidance of Dr. Honeyman, who assured us that the different rock beds of Nova Scotia are so well defined that an expert could locate almost any of the pebbles found in the gravel beds of Halifax. The doctor picked up pebbles which he identified as coming from the Cobequid hills, others from the amygdaloid beds of Blomidon, and still others from various places.

The Montague and Waverly gold mines were visited on the way to Windsor. But little work is now being done at either of these mines. At Montague a large number of specimens which showed visible specks of gold were found by the party. The impression gained from both these mines was that the

veins are narrow, six inches or less of quartz, but that they seem to make a good show of gold per ton of vein stone. Capital does not seem to have been much attracted here, whether from lack of confidence in the mines or in the men, or from want of proper representation, we did not ascertain.

The Windsor plaster quarries are well worth a visit from a mineralogist. Beautiful selenite crystals are found there beside ulexite, howlite and anhydrite. Cape Blomidon, celebrated for the beautiful trappean minerals which have come from it, could be reached from Windsor only by chartering a special steamboat for the trip. The mineral beach is thirteen miles long and it is said to be entirely a matter of luck whether or not a party may land at a spot which is abounding in good specimens. The minerals which are sought here, occur originally filling cavities in the trap. The trap crumbles and falls off the cliff in the spring as the frost melts, and the most perfect minerals are obtained then. Fine specimens of stilbite, hewlandite, scolecite, amethyst, and laumontite, were found by the party.

Returning by way of Annapolis to St. John, we made way with some little trouble to the Lake George antimony mines, which are not worked at present. There seems to be no lack of ore and the mine is well equipped with machinery and furnaces. The mine has been through various vicissitudes in having men who were skillful in some respects, but unable to adapt their knowledge to the needs of the country. Some of its superintendents were expensive in one thing, some in another. And so an apparently valuable property is lying unused awaiting a prudent, economical management.

Our work of observation was finished by an interesting trip from Bangor to the Katahdin iron works, situated 19 miles from Milo, a small town on the Bangor and Piscataquis Railroad. They have a charcoal furnace in successful operation and are turning out a good quality of iron. The ore deposit is one of peculiar interest to the geologist. It is apparently of recent age and is still in process of formation. The trees growing on

the deposit are mostly aspens and birches, which do not seem ever to have attained a diameter of over six or eight inches although undisturbed by man. When they have reached about this size they have fallen, and become changed by the chalybeate springs, into iron ore, to be followed in turn, by the succeeding crop. A large proportion of the ore which constitutes superficial beds from two to nine feet thick is composed of fossilized leaves and limbs of trees which are so well preserved that the species can be identified at a glance.

The thanks of the party are due to Mr. W. B. Hazeltine for his kindness in giving reduced fares on the Boston and Bangor boat, and to Mr. H. D. McLeod for reducing the fare from St. John to Bangor. These helps often times enable students to go on these expeditions who otherwise could not do so.

ROBERT H. RICHARDS.

LOWELL FREE COURSES FOR 1874–75.

General Chemistry. Twenty-four laboratory exercises.
Qualitative Analysis. Twenty-four laboratory exercises.

President J. D. Runkle:—

DEAR SIR:—For the last few years the Lowell Courses in Chemistry have consisted of Laboratory Exercises in General Chemistry and in Qualitative Analysis. One winter a course of lectures was given, but experience then and since has seemed to show that more good can, on the whole, be accomplished by laboratory exercises.

The number of tickets issued is, of course, limited by the size of the laboratory at my disposal. The number of applications is very greatly in excess of our accommodations, but many of the applicants have no appreciation of the nature of the course and if they receive tickets, either make no use of them or, after attending for a few exercises, appear no more. Others who would profit by the course are thus prevented from attending. As we have this same trouble year after year, I would respectfully suggest that applications for the courses in Chemistry be made in person.

The majority of the persons who avail themselves of the opportunities offered are school-teachers and practicing pharma-

cists, although these two classes are not the only ones represented: the two sexes are represented about equally.

In General Chemistry, those who are beginning the subject use Eliot and Storer's Elementary Manual, and perform, each for himself or herself, the experiments there described; those who have previously studied the subject experimentally proceed from the point already reached. In order to derive any profit from the course it is necessary that time be given to the study of the subject outside of the laboratory, and only those who take sufficient interest in the matter to be willing to devote the necessary time can expect to be benefited by the laboratory work. In Qualitative Analysis each person works independently of every other, and the progress made depends upon the individual. Except the beginners, who use a prescribed textbook (Eliot and Storer's Manual), the students use any book with which they are more or less familiar, and the selection of substances analyzed is made, as far as possible, with a view to the occupation of the student or to the use he or she is likely to make of their knowledge.

The class of 1874–75 numbered forty-five in all. No account was kept of the individual attendance, but the number present at each exercise was about thirty-five on the average. With some of the more advanced members of this class, I tried an experiment to see how much it might be possible to accomplish in *Quantitative Analysis* during such a course of twenty-four two-hour exercises. We labored under many disadvantages for lack of proper space and on account of the shortness of the exercises; but, in spite of this, the results were very satisfactory. Those who pursued this course (all ladies) acquired an idea of the general principles of gravimetric and volumetric analysis and of certain parts of stoichiometry, and had some practice (limited to be sure), in the application of the principles to special cases. It seemed, however, impracticable, with our present laboratory accommodations, to undertake regularly a "Lowell" course in Quantitative Analysis, but for the class

of persons from whom, at present, comes the greatest demand for such instruction, namely, the teachers, provision has this year, 1875–1876, been made by the Institute.

Yours Respectfully,

WM. RIPLEY NICHOLS.

Practical Geology of the United States. Eighteen lectures.

President Runkle: —

In the months of November, December and January, 1874—75, I gave an evening course of free lectures on the Economic Geology of the United States, of which the following is a synopsis: —

I. Preliminary notions of geology and the classification of rocks and formations.
II. History of granites and granite-like rocks.
III. The crystalline stratified formations.
IV. History of mineral veins and ore-deposits.
V. The Paleozoic formations, their origin and history.
VI. The Mesozoic and more recent formations.
VII. Relations between the geology and the physical geography of the United States.
VIII. Building-stones; granites.
IX. Marbles, sandstones and slates.
X. The iron ores of the crystalline rocks.
XI. The iron ores of the paleozoic rocks.
XII. Copper ores and mines of native copper.
XIII. Gold and silver mines.
XIV. Salt, and gypsum; mineral waters.
XV. } Coal deposits, history, development, economic importance.
XVI. }
XVII. Petroleum and its geological relations.
XVIII. The recent deposits; soils and clays.

The object of these lectures was to give in the first place such notions as would serve to make intelligible the great fea-

tures of our geology and the relations of these to the physical geography of the country, and in the second place to describe our mineral resources, their geological history and their economic development. T. STERRY HUNT.

Lantern Projections. Eighteen lectures on the use of the Lantern as a means of illustration in teaching.

President Runkle: —

The course of lectures in Lantern Projections was designed especially for teachers who wished to use this valuable means of illustration in their daily work. The ground covered was substantially as follows: Sunlight, description of the *porte-lumière* and various forms of heliostats. The magnesium light, method of making and burning magnesium. The calcium light, methods of making oxygen and hydrogen, methods of storing by gasholders, reservoirs and bags. Various forms of burners, substitutes for the lime cylinder, the Bude light. The electric light, regulators, forms of batteries, theory of their action, magneto-electric machines. Photometric measurements of the various lights. Experiments with the direct light, shadow and penumbra, phosphorescence and fluorescence. Theoretical considerations involved in the methods of projections, refraction, lenses, chromatic and spherical aberration. Construction of the lantern, various forms of condensers, their advantages and defects. Forms of projecting lenses, size of image, forms and dimensions of screens. Objects employed, drawing and painting on glass and gelatine, photographs. Projecting small objects, opaque objects, Chinese fireworks, chromatrope, dissolving views. Stroboscope, application to revolving wheel, tuning fork and electro-magnetic engine. Tanks, three methods of exhibiting chemical decompositions, convection, capillarity, electric decompositions, crystallizations. Vertical lantern, magnetic phenomena, waves, cohesion figures. Galvanometers, method of projecting objects in two planes at once, mirror galvanometers.

Lissajous' experiment, compound pendulum, Crova's apparatus. Lantern microscope, precautions and defects. Polarization of light, theory of apparatus employed, parallel beam, selenite plates, compressed, bent and unannealed glass, converging beam, crystals, mono-chromatic light. Spectra, method of projection by sunlight, calcium and electric light, spectra of metals, reversion of soda flame, monochromatic light, imitation of spectra with black lace curtains. The lectures were fully illustrated by various forms of lanterns, and the object aimed at was not merely to describe and exhibit the various phenomena, but to explain how the apparatus should be made and arranged and what precautions were essential to secure success.

E. C. PICKERING.

Elementary French. Eighteen lessons.

President Runkle:—

I have the honor to submit to you the following report on the work assigned to me in the Lowell Evening courses for the winter of 1874–75.

Beginning on the 16th of November, 1874, our exercises took place, without interruption, on the Mondays and Wednesdays of every week, until brought to a close on the 13th of January, 1875. The class on the opening night numbered in the eighties; in the few succeeding nights, however, this number gradually fell off, until it reached a steady average of about fifty persons, who remained, to the end, assiduous attendants.

While adhering strictly to the letter of the programme, I availed myself of what freedom was left to me in the arrangement of details, selecting out of the topics included under the general head "elements" only such as appeared to me to be more important or more appropriate to my audience; thus, I left out many minor points, sketched others with a rapid outline and endeavored to set off among all others the characteristic parts of speech, the *pronoun* and the *verb*. There, in fact,

is found whatever originality or richness of forms the French has inherited from the Latin, and there also the student meets with most difficulties. Besides, the treatment of these two topics carries with it several questions of syntax, such as the construction or position of the different parts of the sentence, the arrangement of words in negative or interrogative clauses, etc., all of which points pressed themselves upon our attention and furnished us with an abundant material until the very last minute. Each exercise was divided into two parts; 1. A summary exposition of the topic on hand, with illustrations on the black-board. 2. An application of the principles and rules thus announced, by means of sentences given out to the students during the last twenty minutes of the lesson, to be translated into French and written down while the explanations still rang in their ears. These translations were handed in on leaving the class, carefully examined between the exercises, and the errors pointed out at the opening of the next lesson. In this way I was enabled to follow the progress of the class and to hasten or slacken speed as the case required. I may add that these papers, for the most part, did honor to the earnestness of purpose as well as to the understanding of the writers.

A course in "Elementary French" must needs include exercises in *pronunciation*. Here again we had to follow a short cut method; the study of pronunciation is a laborious process whereby the student's ear is inured to strange sounds and the clumsiness of his organs overcome; all this requires time and a constant, personal commerce between the teacher and the pupil; as we were limited in regard to both requisites, I restricted myself to exposing clearly the scheme of French sounds and the peculiar structure of the French syllable; then, I requested the class, as a unit, to scan aloud some of Lafontaine's fables, keeping time, giving out every sound distinctly and articulating each syllable as if it were a word in itself. The class brought to this very simple, almost childish, exercise, so much good will, that it was pursued, to the last, for a few minutes in each lesson, and we trust, not without profit, since

the students were thus taught a stringent observance of the syllabic division of words, a principle of utterance too often disregarded in our hasty methods.

A last remark, with quite a different bearing, I must also submit to you, Mr. President, as it goes far towards explaining what success the class may lay claim to, namely; although the French course is intended for persons desirous of beginning the study of that language, such real beginners form but an exceedingly small percentage of the entire attendance. In fact, without any previous training, a person is at a disadvantage in so large an assemblage. I hesitate to say that there were none of that class; yet, barring other proofs, a careful examination of the written translations bears witness to the fact that a very large majority of the students had studied French, whether at school or under private tuition, before joining our course. With such scholars alone could our hasty march find favor and for such ones, mainly, be fruit-bearing; it was for them not a new, hardship-like study, but a mere review of things and facts previously known. Whether this unrequired preparation of so great a majority of the attendants ought to be taken in consideration in the shaping of a subsequent course is a point which I must, Mr. President, leave to your consideration.

Yours, Very Respectfully,

JULES LUQUIENS, *Instructor.*

December 20, 1875.

Modern Philosophy, from Descartes to Hegel. Eighteen lectures.

President J. D. Runkle: —

This series of eighteen Lectures was attended by some forty persons, about a third of whom were women. Fifty-four were present at the first lecture; at the last, there were thirty-five.

The following is a synopsis of the course: —

Lect. I. *Introductory:* The Definition of Philosophy, the Group-

ing of the Historic Systems, and the General Character of the Modern Movement.

Lect. II. *Descartes:* his Epoch, his Genius, and his Claims as Founder of Modern Philosophy.

Lect. III. *Descartes*— the Details of his System: an explicit Dualism, but at the same time an implicit Monism; its inconsistency as Dualism, its consistency as Monism.

Lect. IV. *Geulinx, Malebranche, Hobbes:* Attempt, by the two former, to save the Dualist view of Descartes by the added theories of *Occasionalism* and *Vision in God;* by the latter, to bring out the required consistent Monism by the theory of *Materialism.*

Lect. V. *Spinoza* — General Estimate: Cartesian implicit Monism made explicit as Pantheism.

Lect. VI. *Spinoza:* Outline of his *Ethics.*

Lect. VII. *Locke:* Transfer of the Problem of Philosophy from the question of the Nature of Being to that of the Scope and Worth of Thought; Beginning of Empiricism, and preparation for Skepticism in the empirical Principle.

Lect. VIII. *Leibnitz:* The Revolt from Empiricism, and Return to the Question of Being; Preparation for Idealism in the *Monadology,* a system of an infinitude of *Substances* made one in *Essence* by the Pre-established Harmony.

Lect. IX. *Berkeley:* Idealism becomes explicit in the form of a Dualism of Spiritual Substance, Creator and Creature; the Insubstantiality of Matter as a corollary of Empiricism.

Lect. X. *Hume:* Return to the question of the Worth of Thought; thorough comprehension of Empiricism as in reality Skepticism.

Lect. XI. *Reid, and the Scottish School:* Revolt from Skepticism in the interest of Common Sense; Hypothesis of the Transcendental origin of the Principles of Common Sense.

Lect. XII. *Kant:* The Transcendental principle comprehended; the transcendentalism of Common Sense vanishes in Kant's Transcendental Skepticism, as Empiricism completed itself in Hume's Empirical Skepticism.

Lect. XIII. *Kant:* His Theoretical Philosophy; the *Critique of Pure Reason* in outline.

Lect. XIV. *Kant:* His Practical Philosophy; attempt to compensate for the skepticism of the *Critique* by the doctrine of *Ethics* and of

Good Judgment; Sketch of the *Critique of Practical Reason* and of the *Critique of Judgment*.

Lect. XV. *Fichte*: The removal of Kant's hypothetical "Thing in Itself" converts his Transcendental Skepticism into Subjective Idealism; the Human Ego the only Substance; all else, even God, only the Form and Mode of man's existence; Pananthropism, as inverted Spinozistic Pantheism.

Lect. XVI. *Schelling*: Reaction from Fichteanism, on viewing it as implicit Single-Individualism; Hypothetical identification of Being and Thought; the NEITHER, as abstract Common Essence of Spirit and Matter, proposed as the Sole Reality or Ground of All.

Lect. XVII. *Hegel*: Absolute Idealism; Reality as PERSON, *i. e.*, as the Living Unity in which the twofold of Subject and Object (Thought and Nature) given by Reflection, is taken up by means of the mutual neutralization of its two terms.

Lect. XVIII. *Hegel*: Sketch of the *Logik*, with especial reference to its doctrine of the *Begriff* as the real unit of thought.

GEORGE H. HOWISON,
Professor of Logic and the Philosophy of Science.

Elementary Principles of Mechanism. Eighteen lectures.

President J. D. Runkle:—

DEAR SIR:— The following is a synopsis of the work done in the Lowell free course of eighteen lectures on the Elementary Principles of Mechanism given by me last session. In these lectures, which were intended for persons actually engaged in work in machine shops and in similar occupations, an attempt was made to present, as far as time would allow, the mathematical principles which underlie a correct construction of the different mechanical combinations and their adjustment to the purposes they are intended to fulfill; and to give such explanations as would enable one to make correctly and understandingly computations and designs for practical cases.

The discussion of Belts and Pulleys and of Gearing occupied the greater part of the time, the remainder being devoted to the study of Cams, Linkwork and Universal joints.

Under the head of Belts and Pulleys, the following were the subjects discussed: —

Advantages and disadvantages of connections made by belts and cords, and cases when it is desirable to employ them. Open and crossed belts and cords. Lacing, splicing and rivetting. Limiting speed and length of wire ropes. Bearing pulleys for wire ropes. Construction of pulleys for belts, cords and wire ropes. Lateral stiffness of belts. Climbing of belt. Crowning of pulleys. Fast and loose pulleys. Quarter twist. Connection of non-parallel shafts by belts, [illegible]. Guide pulleys. Reversing gears where fast and loose pulley is used. Computations under given conditions of diameters of pulleys, velocity ratio of pulleys, speed of belt, length of belt, etc. Conical pulleys; 1st, Stepped cones, computation of the proper diameters: 2d, Speed cones, determination of swell. Non-circular pulleys. Velocity ratio. Straining pulleys. Fusee. Chain pulleys. Suspended pulleys, etc., etc. Tension on each side of the belt. Coefficient of friction of leather on iron. Strength of belting. Power transmitted by belts. The last four being discussed chiefly in the light of the experiments of Gen. Morin and Mr. H. R. Towne.

Under the head of Gearing the following subjects were studied: —

Computation under given conditions of diameters of pitch surfaces speed, etc., of spur and annular wheels and of rack and pinion. Determination of the pitch surfaces of bevel gears. Screw gearing. Frictional gearing. Non-circular gearing. Eccentric and elliptical gears and rolling cams. Rules governing the pitch and number of teeth. Crown wheels. Hooke's stepped teeth and Hooke's screw gearing. Trains of wheelwork. Computation under given conditions of velocity ratio of gears, numbers of teeth, diameters, etc. Hunting cog. Least number of teeth admissible in a pinion. Proper number of intermediate axes in a train. Idle wheel. Dr. Young's least number of teeth in a train, its advantages and disadvantages. Clock trains. Epicyclic trains. Copying lathe. Screw cutting lathe. Cal-

culation of change wheels. Mangle wheel. Determination of the proper dimensions of the teeth of wheels, viz., Addendum, pitch, clearance, thickness of tooth, working depth, etc. Construction of rolled curves. Instantaneous axis. Mode of designing epicycloidal teeth and of constructing the template. Radial flanks. Curved flanks. Case when circumference of describing circle is six times the pitch. Mode of designing involute teeth, their advantages and disadvantages. Determination of the base circle. Cycloidal teeth for racks. The Odontograph and its use.

The time remaining from the above subjects was devoted to the following, viz, : —

Velocity ratio in Linkwork. Drag link. Link for contrary rotations. Link for reciprocating motions. Crank and connecting rod. determination of dead points, velocity, ratio, etc. Oldham's coupling Hooke's joint. Cams. Eccentrics. Construction of cams to actuate 1st, a rocker arm; 2d, a sliding bar. A *very* brief consideration of the slide valve was also made.

All of which is respectfully submitted.

GAETANO LANZA.

ABSTRACTS OF THESES PRESENTED BY GRADUATES OF 1874–75.

DEPARTMENT OF CIVIL ENGINEERING.

Fall River Water Works. Abstract by the author, Samuel E. Allen.

I. In the introductory portion of this review, I have considered the City of Fall River: — 1st, As regards its location; 2d, As regards its general character; 3d, As regards its available sources of water supply, since all these points have an important bearing on the character of the works to be constructed.

II. I have touched on some of the most important points to be considered in the construction of any work of a similar nature. 1st, Probably the point of most importance is that of adequacy; 2d, Perhaps next to the consideration of adequacy is that of economy; 3d, The third consideration is that of safety.

III. In the descriptive portion of the review, I have taken up the arrangements for obtaining the water supply from the lake, and described the most important of them more or less in detail. These arrangements are, the Gate House, Conduit, Engine House and Pumping Engine, the Force Mains to the Stand Pipes, the Stand Pipes, Supply Mains, Water Gates, Hydrants, etc.

The description is accompanied by three drawings. Drawing No. 1 shows a plan of the Pumping Station, No. 2, a plan and

elevation of the Weir and Stand Pipe, and No. 3 shows a plan, half side elevation, and two sections of a Man Hole and Blow-off.

Lattice Girder Bridge. Abstract by the author, Henry K. Burrison.

This particular design consists of an upper and lower boom to withstand the bending action, and a set of diagonals crossing each other at the middle of each panel, to withstand the shearing action of the load. The span of the bridge is one hundred and ninety-two feet, and consists of sixteen panels; the height is eighteen feet, and width fifteen feet clear; the length of each piece is dependent upon these given dimensions, while the *area* of any cross section depends on the stress at that cross section, and the *form* of cross section on the option of the designer, who is guided by the relative position of each piece and the forms which experience has shown to be best. The diagonals are simple bars of rectangular cross section, fastened to the lower part of the upper boom, which is a square cell set on edge, and the web of the lower boom which has an inverted T shaped cross section; the end posts are square cells.

The material used is wrought iron, except the supports for the I beams which are cast. The sustaining power of the bridge is calculated for a dead load of 800 lbs. and a live load of 1200 lbs. per ft. run. As the girder is composed of two simpler ones, the action of the load is considered on each, and the results combined. The diagonals acting as ties, are calculated for a working strength of 10,000 lbs. per sq. inch, while the struts are determined by Gordon's formula, the greatest action of the load alone being considered in every case.

The I beams which support the floor timbers, weigh 200 lbs. per yd. and are calculated to support, beside the floor timbers, a weight of 20 tons, being the greatest weight liable to come from a locomotive on them. The bolts which sustain them are calculated from the same data, and pass through the flange of the lower boom. The horizontal diagonals for wind bracing,

are calculated from a pressure of 25 lbs. to the sq. ft., acting on a surface 192 ft. by 18. The rivets are calculated from bearing area, the bearing of one square inch being considered as 8000 lbs.

Lattice Girder Bridge. Abstract by the author, C. A. Church.

The first part of the thesis is taken up by a description of the abutments and of their foundations. This is followed by a description of the details of the bridge.

Next is given a general description of the method of calculating the stresses of the diagonals and chords, followed by the calculations of these stresses, and the net area of cross-section required in the different pieces.

The calculations for the number of rivets required in the diagonals and joints of the chords are next taken up, after which the maximum stresses to which the floor is subjected, are calculated, and the sizes of the stringers and cross-girders fixed accordingly.

The last subject taken up is the determination of the weight of the bridge. The weights of the different parts of the bridge are first calculated in order, following which is a table giving a summary of the weights.

Salem Water Works. Abstract by the author, Frank S. Dodge.

I have divided my thesis into two parts, the first relating to the subject of water works in general, and the second to the works belonging to the city of Salem, Mass.

Part first embraces,

1. A few of the advantages of an abundant supply of pure water.
2. An account of some ancient and celebrated aqueducts.
3. The difficulties to be met in the construction of reservoir banks, and the various means of overcoming them.
4. A list of general principles to be followed, and which are essential to the durability of the structure; also the means of preserving the purity of the water.

5. Methods and materials for rendering a reservoir water tight, especially at the joints between puddle and masonry or pipes.

Part second includes

1. A short account of the introduction of water into Salem, with a history of the old "Salem and Danvers Aqueduct Co."

2. A description of Wenham Lake, the source of supply, embracing its situation, capacity, quality of water, etc.

3. A detailed account of the works, beginning at the source, and extending through the whole in the order in which they occur, viz., the iron conduit pipe, gate chamber and screens, brick conduit, pump well (with the difficulties encountered in laying the foundations in quicksands), engine house, Worthington Pumping Engines, force main, check valve, branch main and stand pipe, reservoir, effluent pipes, supply main, and system of distribution.

The reservoir, being very important and difficult in construction, is treated in its minutest details. It is described in its situation, elevation, capacity and construction of its parts, including puddle floor and walls, paving of slopes, effluent pipes with their screens, and supports within the embankment, and the system of surface drainage.

The whole is illustrated by fifteen tinted drawings covering the most important points, and briefly explained in an appendix.

The Iron Bowstring Girder Bridge over the Charles River at Waltham, Mass., by the author, Edgar S. Dorr.

In this thesis I have first presented a description of the bridge and its details from measurements made by myself and others, and from information obtained from the builders, the King Bridge Company of Cleaveland, Ohio. From these data I have calculated the weight of the bridge, and thus obtained the fixed load. The live load for which the bridge was calculated, was given me by the engineers as seventy-five pounds per square foot, the bridge being a road bridge. With these

data I have calculated the greatest thrust at the crown of the bow, and the greatest tension in the main tie, by the formulæ of Rankine, p. 563, Art. 379. By the formulæ of the same article I have calculated the tension and the thrust, if any, in the verticals, and the tension in the diagonals produced by the rolling load. In each case I have computed the dimensions of the pieces necessary to resist these stresses, and compared them with the actual dimensions of the bridge. I have also calculated the strength necessary in the cross beams to support the platform and its load, and the strength of the various joints of the bridge.

I have also made two drawings, one representing the bridge in elevation, plan, and end view, and the other giving details of the bridge upon an enlarged scale.

The Howe Truss Bridge at India Point, Providence, R. I. By William C. Edes.

(Abstract not received.)

Tunnelling. An abstract by the author, Edward A. W. Hammatt.

I have treated this subject under the following subdivisions: — 1st, Preliminary Work; 2d, Sinking Shafts; 3d, Transferring the Line and "dropping" the Levels down the shaft; 4th, Driving Headings; 5th, Excavation and Brickwork of Side Lengths; 6th, The same of Shaft Lengths; 7th, The same of Leading and Junction Lengths; 8th, Centre, and then a few statements in regard to Machine Drills.

I have illustrated my description by sketches in the body of the thesis, and by two plates of drawings, and as the operations of tunnelling in rock consist mostly of blasting and quarrying, I have confined my description to tunnelling through earth, and have had frequent recourse to Simms, "On Practical Tunnelling." My illustrations refer mostly to the Blechingly Tunnel, Eng., although I have made some reference to the Mont Cenis,

Hoosac, and the Beacon Street Tunnels; the latter of which is now in process of construction at Newton Centre, Mass., for the Boston Water Works. I regret to say that I was unable to obtain as much information in regard to Machine Drills as I could have wished.

Brookline Water Works. Abstract by the author, Edward A. Handy.

The subject of my thesis is the "Brookline Water Works." I first gave a short history of some of the methods which were proposed to supply Brookline with pure water, and stated as clearly as I could the reasons which led the Commissioners to adopt the present system, rather than any of the others. The works, as now built, consist essentially of a filtering-gallery on Cow Island, in the Charles River, a short distance below the town of Dedham, a pumping-station situated on the edge of the marsh about 3000 feet distant from the gallery, a stand-pipe 14′ in depth on Walnut Hill in Brookline, and a reservoir, with a capacity of 6,500,000 gallons, situated on Fisher's Hill.

I gave a description of each of these essential features and spoke of the various difficulties that were met with in their construction. In speaking of the filtering-gallery, I entered upon the interesting questions which arose concerning the probable source from which the water is derived, and mentioned the various experiments by which it was proved almost conclusively that the water is supplied by springs and does not come from the river at all. The drawings which accompanied my thesis, were of details of such parts of the work as would serve to make my descriptions more easily understood. I did not touch at all upon the question of town distribution, as that in itself would have given material enough for an entire thesis.

The Holly versus the Reservoir System of Water Works. By Clarence L. Howes.

(Abstract not received.)

The Holyoke Dam. Abstract by the author, William F. Huntington.

The site chosen for the dam at Holyoke seems to possess all the advantages that could be desired. There is an available fall of upwards of sixty feet; the bed of the river at the place where the dam has been built is composed of Connecticut River sandstone, which furnishes an excellent foundation for the dam; and the lay of the land below the dam is peculiarly adapted for the construction of canals and mills.

The attention of capitalists was early turned towards the immense water power afforded by the Connecticut River at Hadley Falls. In 1847 a stock company was organized. The following year this company proceeded to build a dam across the river, a full description of which is given in the thesis. This dam was finished November 19, 1848, and was carried away the same day, before the water had risen as high as its crest. Some of the reasons that were given for the failure of the dam are stated in the thesis. In order to determine whether or not it was capable of resisting the pressure brought to bear upon it, the forces acting at a section six feet in width were calculated. From these calculations it appeared that the principal defect in the construction of the dam, was that the slope of the up stream side was too steep. It is said that the dam gave way by sliding upon its foundations. Had the slope just spoken of been less steep, the line of action of the resultant of the forces acting at a section of the dam would have been more nearly vertical, and it is probable that the dam would not have yielded to the pressure of the water, in the way that it did.

During the year 1849 another dam was erected by the Hadley Falls Company. A description of this dam and of the way in which it was built, is given in the thesis. The forces acting at a section of the dam were calculated, and from these calculations it was shown that the dam was sufficiently strong to resist the pressure of the water brought to bear upon it.

An examination of the dam spoken of last, was made in 1868, and it was found that the rocky bed of the river had been worn away by the continuous fall of the water. In order to protect the foundations from being undermined, an apron was built in front of the dam. This apron consists of a crib-work of logs loaded with stone.

The head gates at Holyoke are shown by drawings, which are fully described in the thesis.

The volume of water flowing in the Connecticut River at Holyoke at ordinary times, is estimated to be 5200 cubic feet per second. The available fall is sixty feet. From these data the water power was calculated to be equal to 35,400 horse power. This power is distributed by means of three canals at different levels, as described in the thesis.

The Lawrence Dam. Abstract by the Author, W. F. Sargent.

The Essex Company, the principal owners of the water power and canals, and the principal owners of the town, have erected the dam and canals. They dispose of the water power to other Companies on certain conditions, which are specified with great care and minuteness on the printed proposals for their sale. They define a "mill power" to be thirty cubic feet of water per second when the head and fall is twenty-five feet, which is to be graduated to a greater or less quantity as the head and fall shall be less or greater than twenty-five feet.

Charles S. Storrow, Esq., was Principal Agent and Chief Engineer. Capt. Charles H. Bigelow was Assistant Engineer, and under the immediate direction of the latter the works of the dam and canal were carried forward to their completion, and in accordance with the original designs.

The excavation for the foundation of the dam was commenced August 1st, 1845. The first stone was laid Sept. 19th, of the same year, and the dam was completed in 1848. The whole structure is of solid masonry laid in cement. The foun-

dation is imbedded in the solid rock, and bolted to it with iron. The structure is 1,629 feet long, including the wing-walls; the overfall is 900 feet long. The north wing-wall is constructed to unite with guard locks at the head of the canal. The dam is 35 feet thick at the base and 12½ feet thick at the lower end of the coping crest stones. Its greatest height is 40½ feet, and its average height is 32 feet. The water falls from 25 to 27 feet, giving an effective fall of 28 feet for the whole of the river.

The lower front course of stone resting upon the rock is composed entirely of headers, which are let into the rock in such a manner that they cannot slip. All the front courses, and the coping crest stones are of hammered granite. The crest stones are all laid as headers, and each stone is bolted to the stone beneath it. The interior of the dam is composed of common rubble masonry laid in cement. The face has a batter 1 in 12, the crest has a batter of 1 in 3, and the rear of the dam is laid in steps, having the general slope of 45°. The water is taken from the pond produced by the dam, by an artificial canal, which is about four hundred feet from, and nearly parallel to, the river, and in this space are the sites for the mills. The dam crosses the river obliquely, and is slightly arched up stream.

After giving a general and detailed description of the dam and canals, I calculated the stability of the dam, both with reference to overturning, and to sliding, and under two conditions, first, supposing the water to be just on a level with the top of the dam, second, supposing the water to be ten feet deep on top of the dam, and I found it stable in all cases.

On the Coefficient of Expansion of dry saturated Steam in an unjacketed cylinder. Abstract by the author, James H. Head.

Professor Rankine states that the coefficient of expansion of dry saturated steam in an unjacketed cylinder is $-\frac{10}{9}$, and in a jacketed cylinder $-\frac{17}{16}$. That is $p \propto b^{-\frac{10}{9}}$ and $p \propto v^{-\frac{17}{16}}$ when p represents the absolute pressure and v the volume of the steam. These values of the coefficient were determined by calculations which were based on theoretical deductions from the known nature of steam and work. But they were not determined by direct experiment.

The purpose of this investigation was to ascertain whether the values calculated by Rankine, agreed with the results of direct experiment with ordinary steam in ordinary engines, for it was believed that the effect of an important influence was overlooked by Rankine in his calculations.

Twenty-five or thirty sets of indicator cards taken from different engines having unjacketed cylinders, were obtained for examination.

Generally saturated but sometimes superheated steam was used. No data was obtained from jacketed cylinders. The method which was used to obtain the coefficient from the indicator diagrams, was the general one devised by Professor E. C. Pickering, for the establishment of any physical law. A paper detailing the method was read by him at the meeting of the American Academy of Arts and Sciences, held May 12, 1874, and afterwards published by that Society.

As far as this investigation goes, it appears to be true that the coefficient of expansion given by Rankine for unjacketed cylinders is incorrect for practical usage. For,

First, The law expressing the relation of pressure to volume when either saturated or superheated steam is expanding in an ordinary unjacketed steam cylinder is not necessarily of the form $p \propto v^n$. Only in the case of one or two expansion curves

could the relation be expressed by that form, and approximate closely to the truth.

Second, On expressing the relation approximately by the form $p \propto v^x$, I find that the coefficient x is not constant, but that it varies in different engines, and even in the same engine if the point of cut-off be changed.

In the cases which I examined I found it to vary from —.65625 to —1.0200. These extreme coefficients were both derived from saturated steam diagrams taken from the front end of the Harris-Corliss Engine in the Mechanical Laboratory of the Massachusetts Institute of Technology. Its cylinder is 8.01″ in diameter and its stroke 24″. The coefficient — .65625, was derived from diagrams taken with an apparent cut-off of $\frac{1}{18}$. The steam pressure was 71 pounds per sq. in. The speed of the engine was 57 revs. per minute. The coefficient — 1.0200 was derived from diagrams taken with a real cut-off of about $\frac{3}{4}$. The steam pressure was 70 pounds per sq. in. The speed of the engine was about 59 revs. per minute.

NOTE. — The author, in closing his thesis, expressed the hope that he should be able to carry this investigation further; but his sudden death on Aug. 18th, closed this and all his other earthly labors, and ended a life of great nobleness of character and bright promise.

The Construction of Gear Teeth. Abstract by the author, Thomas Hibbard.

I have not attempted to consider, in this thesis, all the bearings and details of the subject of designing teeth, but have called attention to some of the most important points, and have discussed a few of the principal methods by which teeth are constructed at the present day.

After a few introductory remarks, in regard to the construction of teeth in the past time, I have given some of the reasons for the selection of the proper curves for teeth, and have distinguished between the two great classes : — viz., involute teeth, and epicycloidal teeth. It is the latter class which is

principally discussed in this thesis. A few of the merits and demerits of involute teeth are spoken of.

Attention is then called to the fact that there are many ways of approximating to the true epicycloidal curve, some of which have very little effect on the true action of teeth, while others are exceedingly detrimental. The use of the describing circle in drawing flanks and faces to work together is explained. Then follows an explanation of the method of drawing rolled curves, and consequently curves for teeth, by means of normals, when no describing circle is used. In connection with this, I have added one or two problems which arise out of a consideration of this method, such as: — to find the path of contact; to find meeting points in the parts which work together; to draw clearing curves, etc. I illustrated this method with its problems with parallel flanked teeth on gears of 12 and 10 inches radii.

The importance of selecting the proper describing circle, if constructing teeth by the correct method, is next discussed. Among others, these four important elements depend on the size of the describing circle: — 1st, The number of teeth in gear at any one time, and consequently the force that can be transmitted by them. 2d, The thickness of the teeth at the base, and, hence, their strength. 3d, The extent of wearing surface on the flanks and faces of the teeth, and, therefore, the durability of the teeth. 4th, The obliquity of action of the teeth, and the friction produced thereby on the bearings of shafts. The influence of the size of the describing circle upon each of these elements is discussed.

In order to clearly point out the peculiarities and differences of the various methods of designing teeth now in common use, I have drawn the outlines of two teeth of large dimensions by each method discussed. For convenience of comparison I have traced them on separate sheets, so that they can be superposed on each other, and most easily present to the eye the various points of difference.

I have discussed the: — (*a.*) Parallel flanked teeth; (*b.*) Willis' Odontograph teeth; (*c.*) Rankine's approximate method; (*d.*) Haswell's approximate method; (*e.*) Radial flanked teeth; (*f.*) Molesworth's approximate method; (*g.*) Hussey's method; and (*h.*) the correct method of finding a series of circular arcs to which the true curve is tangent.

To compare with Willis' and Rankine's, I have drawn the same teeth by the correct method (*h.*), using the same describing circles which were used in those methods. The approximation of those methods is thus made clearly evident. With each plate I have endeavored to point out the chief peculiarities, and advantages and disadvantages as regards correctness of form, correctness of action, strength of teeth, obliquity of action, etc.

The length of addendum is then treated of, and its influence on the action of teeth. Rules for the selection of the proper addendum to give required results, are presented, together with a short discussion on the length of the arc of action most suitable for general cases. Willis' rules for addendum are given, and by them is calculated a short table for the length of addendum which would be given to certain gears, providing the arc of action was 1.4 times the pitch. The sizes of gears were selected from the pattern list of the Lowell Machine Shop. The variation in length of addendum with the number of teeth is proved by this table.

In closing, there are a few remarks about the selection of a proper method of designing teeth, which selection depends on the judgment of the designer and his knowledge of what has been done, whether that knowledge is derived from a study of good books, the opinions of practical men, or his own experience.

The Crank as a means of converting Reciprocal into Circular Motion. Abstract by the author, J. Austin Knapp.

This thesis begins with an historical account of the use of the crank as a means of converting reciprocating into circular mo-

tion, and of the erroneous opinions which mechanicians have from time to time held regarding some of the more subtile forces developed during its action. The tendency to avoid the crank engine by the invention of rotary engines is referred to, and the theories of Mr. Charles I. Porter, of the Allen Engine Co., are then discussed.

Most of the mathematics of the thesis was given to Mechanical Engineering students of the Institute, by Professor Channing Whitaker, during the sessions of 1873–74 and 1874–75.

The principal points discussed in the thesis, show how to find the following things: —

(*a*) The crank pin position from that of the piston.

(*b*) The piston position from that of the crank pin.

(*c*) The velocity ratio and the actual velocity of the piston and crank pin, at any point of the stroke.

(*d*) The rate of acceleration or retardation of the piston at any point of the stroke.

(*e*) The force producing acceleration or retardation at any point of the stroke.

(*f*) The relative pressures acting on the piston along the connecting rod, perpendicular to the guides, perpendicular to the crank arm and along the crank arm.

The work is illustrated by numerous diagrams representing the positions, velocities, rates of acceleration, forces and pressures before referred to, and also showing the effect of short cut-off and of heavy reciprocating parts as modifiers of these pressures.

Several of the formulæ are applied to the case of an Allen Engine having a cylinder 16″ diam., with 30″ stroke, and making 120 revs. pr. m. The reciprocating parts of this engine weigh 1200 lbs.

Governors. Abstract by the author, Wilfred Lewis.

The purpose of the governor is to maintain the prime mover to which it belongs at a constant uniform speed. The object of

the present thesis is to show how far, theoretically, it is possible for a governor to accomplish this purpose. Accordingly, the principles upon which the various governors considered, depend for their action have been discussed. No special classification has been followed, but according to that given by Rankine, the governors contained in this thesis might all be comprised under the head of position governors, which might again be divided into those which are in principle either approximate or isochronous.

The common pendulum governor, originally invented by Watt, appears to have been the first form used on the steam engine. Beginning with this, its operation is, in the first place, considered independent of friction and resistances to be overcome by the collar, and then the effect of such resistances upon the speed of the engine is shown, and a formula deduced by which the proper weight for the balls may be calculated when these resistances are known, and any desired degree of sensitiveness assumed. This governor can in no case be perfectly isochronous, but there are several ingenious varieties, among which are mentioned the loaded pendulum governor, Porter's governor, and one or two peculiar devices for communicating the motion of the balls to the collar.

Under the subdivision of "isochronous governors" a description is taken from Rankine of his "Isochronous Gravity" governor and the parabolic pendulum governor.

Waters' spring governor and the Huntoon governor are also classed under the same division, and the principles discussed upon which their good qualities depend. As generally constructed, however, it is shown that in Waters' governor these principles are not perfectly complied with, but are sacrificed for the purpose of allowing the governor to be readily adjusted for different speeds.

The Huntoon governor differs in principle from most of the others, and seems to leave very little room for improvement.

Cylinder Condensation. Abstract by the author, Thomas D. Plympton.

This thesis gives the calculated results of an experiment upon cylinder condensation. The experiment is one of a series, made in the Mechanical Laboratory of the Institute during the winter of 1874–75, for George B. Dixwell, Esq. The pressure of the superheated steam was 70 lbs. per square inch. The temperature of the steam was 590° F. The real cut-off was about ¼.

I commence with a description of the apparatus used; and then of the manner of working up the results. I give the record of the most important readings, and the results of some preliminary experiments on the clearance and leakage of the engine. The following is a list of some of the results calculated from this experiment.

(1.) The horse power produced.

(2.) The total heat of the exhaust steam as derived from the calorimeter measurement.

(3.) The weight of water used per horse-power per hour.

(4.) The weight of steam in cylinder per stroke, from the pressure and volume given by the mean card, on the supposition that the steam is saturated.

(5.) The equation of the expansion curve for each end of the cylinder, and the point of cut-off.

(6.) The weight of steam passing through the cylinder per stroke from small tank measurement, which, when corrected for compression and leakage in and out, is the true weight of the steam in the cylinder.

(7.) The pressure at different points of the stroke corresponding to this weight, on the supposition that it is dry, saturated steam.

(8.) The temperature of the steam in the cylinder at different points of the stroke.

(9.) The total heat of the steam in the cylinder at different points of the stroke.

Abstract of Thesis on Steam Pumps. By F. T. Sargent.

A pump is a device for passing a fluid through a tube. An early account of such a contrivance states that Danaus, an Egyptian, assisted by his fifty daughters, dug wells, and by means of pumps supplied the city of Argos with water. This was probably, the first water supplying company ever formed, dating somewhere about 1485 B. C. Some suppose, however, that Ctisibus, who was an Alexandrian, and lived 224 B.C., was the first to invent the pump. The pump was described by Hero, 150 B. C.

Among the first practical applications of steam was that of the Marquis of Worcester for raising water, about 1630. His device is often mentioned as a steam engine; it was, however, a steam pump, as will be seen from his description of it, in his century of inventions. But Worcester's pump was not used to any great extent.

In 1699, Capt. Thomas Savery improved on Worcester's pump, by combining with it a contrivance for producing a vacuum by the condensation of steam. This machine, however, would not raise water more than sixty feet. Newcomen improved on Savery's machine, and in 1714 built his first pumping engine. It could be placed on the surface near the mouth of the mine. Those previously used were placed in the shaft, one above the other, perhaps fifty feet apart. In 1720, Beighton applied the hand gearing. In 1775, Smeaton built a pumping engine having the parts so much better proportioned than those preceding it, that he increased the duty of the pump 50 per cent. Watt appeared about this time, 1776, with his pumping engine, making it a new machine, and in 1785 he had greatly perfected it. Engines are built, at the present time, having the same general features as Watt's engine of 1785.

But steam pumps were not to be limited to the mere draining of mines. They are now used for almost every imaginable purpose. Their demand has not exceeded the supply, if one

may judge from the vast number and variety manufactured. If we believe the makers, we shall conclude that each one in turn is "the best steam pump in the market." It is not my purpose to describe all the different styles and kinds, (this would be impossible,) but simply to give a short description of a few of the prominent ones.

After a short, general description of the manner in which steam pumps work, I have given more in detail a description of the contrivances for changing the motion of the valves at the ends of each stroke, and of any other peculiarities in the construction or the working of these pumps, that I have been able to discover.

In the case of several pumps that are said to have no dead point, I have been able, without much difficulty, to stop them so that they would not start again unless I helped them. Some steam pumps, on account of their long, and too slender piston rod, are liable to tremble considerably, when pumping against very much resistance. Where the resistance is great and where room is to be economized I should prefer one of the class in which the water and steam cylinders can be placed quite near to each other.

The numerous small steam passages of various steam pumps are objectionable, as they are liable to become choked with grease and dirt.

All the working parts of some of these pumps are inside of the body of the machine. They are well adapted for service in exposed and dusty places.

Among the pumps discussed are the Knowles,— Earle,— Blake,— Niagara,— Dayton,— Wright,— Eickemeyer,— Cameron,— Cope and Maxwell,— the Pulsometer, which is very much like a modification of Savery's pumps, — the Cornish pumping engine, the Leavitt pumping engine, and the Worthington Duplex pumping engine. The duty given by the Leavitt engine appears to be "the highest that has ever been obtained, by trial test, of any pumping engine in this country,"

the duty being 103,923,215 ft. lbs. per. hundred lbs. of coal consumed. Sixty or seventy Worthington engines are said to be used at the present time; the duty is comparatively low, but the cost is correspondingly small.

Locomotives. An abstract by the author, J. B. Stanwood.

After giving a short historical sketch of the locomotive, the thesis divides into five distinct parts, which are enumerated and discussed as follows: —

1st. The description and the various uses of the locomotive. Locomotives are used for three distinct purposes, (*a*) for transporting passengers, (*b*) for transporting freight, (*c*) for switching or shunting cars at terminal points, thus arranging these cars into trains for the use of passenger and freight service. The engines for these separate duties have to be constructed differently, as the requirements of each demand; these differences are stated, together with the reasons for them. A brief mention is made of Fairlie's and Meyer's locomotives and of engines used on heavy grades.

2d. Resistance and Traction. It requires work to move cars, on account of the resistance due to the friction at the rails and in the running gear, and the resistance offered by the atmosphere. The rule given by Mr. D. K. Clark (an English engineer) for calculating this resistance, is compared with a table given by Mr. M. N. Forney (an American engineer). The latter is preferred as it more nearly coincides with American practice.

Under the head of *Traction*, it is found that the power of the locomotive is proportional to its weight, within limits. The horse-power is deduced in two ways: one, by simply multiplying the resistance of the train in pounds, by the space passed over, in feet per minute. The product divided by 33,000 will be the horse power. The second way takes into account the size of the drivers, the piston pressure per square inch, and the diameter of the piston or cylinder.

3d. The Combustion of Fuel and the Evaporation of Water. Under this head are considered the values of anthracite, Cumberland (semi-bituminous) and bituminous coals for steam purposes, the results being deduced from a report by Professor W. R. Johnson to the Navy Department, upon American Coals. The advantage obtained by heating the feed-water before it enters the boiler, is discussed, and the amount, in dollars, that would be saved if the water were heated to 150° F., without any additional outlay for fuel, is calculated. This amounts to about $80,000 for 225 locomotives for the space of one year. The Magoon Feed Water Heater is described and a figure of it given.

4th. The Boiler. Under this head, the proportions between heating and grate surface are given, Mr. D. K. Clark being taken as authority. The thickness of shell and the kinds of material used for its construction are stated, together with various methods used by builders in constructing them. The means of obtaining steam room by the use of domes and "wagon-top" boilers is described, together with a rule for the proper clearance for tubes, etc.

5th. The Cylinder. There are four important periods during one complete stroke of the piston. They are the periods of *Admission*, *Expansion*, *Exhaust* and *Compression* of the steam. Each is briefly discussed.

The efficiency of the locomotive G. Twichell, on the Boston & Albany Railroad, is deduced by comparing the amount of work which the coal that it consumes, is capable of doing, with the actual amount of work which the engine does. The result is satisfactory.

DEPARTMENT OF MINING ENGINEERING.

An Article on Salt. By Moses D. Burnet. (Abstract.)

A short introduction is given. The subject is then treated under the following heads: —

1st. What constitutes a good salt.

2d. A short description of the salt manufacture, with a discussion of the properties taken advantage of, and the processes used to obtain purity in salt.

3d. Efficiency of pumping processes, as shown by analyses.

4th. Analyses of foreign and domestic salts, showing their comparative merits.

The Stamps of Lake Superior compared. By C. W. Goodale. (Abstract.)

In this thesis the author has striven to compare the different kinds of stamps from a theoretical point of view. He has calculated the mechanical power exerted per square inch of shoe surface of the stamp. A considerable amount of data has been collected, and a careful description given of the working of the three principal varieties of stamps, namely — the Ball steam stamp, the atmospheric stamp, and the fall or pestle stamp.

Report on Burleigh Tunnel Ore, Colorado. Abstract by B. A. Oxnard.

The ore which was given me to work up is one which comes from one of the veins discovered in running the Burleigh tunnel through the mountain, near Georgetown, Colorado. This enterprise, started by Eastern capitalists, was under the direction of Mr. Charles Burleigh, the inventor of the steam drill of the same name. These drills were exclusively used in the boring of the tunnel. At Georgetown were worked a number

of rich silver mines in this very mountain, and the tunnel was pierced with the double intention of, 1st, Discovering, if possible, new lodes; (as before stated, it was from one of this latter kind of lodes, the ore under consideration came). 2d, Ventilating, draining and otherwise, assisting in the working of the then existing mines.

The sample given me was supposed to be a fair one, indicating the relation between the mineral part and the gangue in the ore, also showing the average richness of the mineral part. It came to me in lumps and powder. The examination was begun by making a search for the minerals contained in it. The greater part was galena and zinc blende, in noticeable quantities, iron pyrites and some copper pyrites. The gangue was mostly siliceous, with little specks of mica here and there, and some feldspar and clay. There was also observed a little decomposed siderite, but not enough to give any trace of CO, in the analysis of the ore.

The work assigned to me was the extraction of the lead and silver from the galena, and that of the silver from the zinc blende. The blende for this did not have to be reduced to the metallic state. The weight of the ore sample was 214 lbs. 12 oz. I went all over this lot, breaking it into small pieces and putting aside a specimen of all the different minerals found, for blowpipe analysis. Their names have been given above. Another object of the picking and breaking up of the ore, was to sort out as much as possible of the galena which was free from blende, as this would save the trouble of separating it by jigging. The ore was thus divided into two lots, one consisting of pure hand-picked galena, the other, of mixed galena, blende, gangue, etc.

These lots by weight then were: —

Blende, galena, etc., portion	176 lbs. 6 oz.
Galena (hand picked)	33 " 6 "
Samples of minerals	4 " 4 "
	214 lbs. 0 oz.

Each portion of the ore was then crushed, first in a Blake crusher, and then between rolls, the galena to $\frac{1}{40}$ in., the blende-galena to $\frac{1}{4}$ in. After crushing, the portions weighed: —

Blende-galena portion	176 lbs. 8 oz.
Galena (hand picked)	33 " 2 "
	209 lbs. 10 oz.

I explain the increase in weight of the galena-blende, by the fact that the galena being crushed first, some of the dust was not removed, but was taken up after with the blende-galena. After the crushing, each part was well mixed, and a sample was taken from each, of which a complete analysis was made.

The two samples being analyzed, first qualitatively and then quantitatively, were found to contain: —

ANALYSIS OF BLENDE-GALENA PART.

Lead	36.00 per cent.
Zinc	7.84 "
Iron	9.81 "
Copper	0.33 "
Sulphur	21.22 "
Silver	0.06 "
Gangue	16.43 "
Water	0.75 "
Undetermined	5.56 "
Total	100.00 per cent.

ANALYSIS OF GALENA PART.

Lead	73.60 per cent.
Zinc	0.45 "
Iron	4.19 "
Copper	0.39 "
Sulphur	16.33 "
Silver	0.128 "
Gangue	2.62 "
Water	0.35 "
Undetermined	1.942 "
Total	100.00 per cent.

The ore after sampling weighed: —

Blende-galena portion	171 lbs. 0 oz.
Sample ditto	5 " 2 "
Galena portion	31 " 6 "
Sample ditto	0 " 10 "
Total	208 lbs. 2 oz.
Dust lost in blende galena portion	0 lbs. 6 oz.
Dust lost in galena portion	1 " 2 "

The galena portion was now all ready to roast, having been picked so as to require no ore-dressing. It was therefore put aside for the time. The blende portion had to be dressed, so as to separate the galena, blende and gangue, from each other. The specific gravity of the two minerals differing very greatly, that of galena being from 7.25 to 7.70, and that of blende from 3.5 to 4.0, a very good separation could be effected by jigging.

As a preliminary step, the ore was separated by sieves into five sizes, viz.: —

1st size, that which remained on $\frac{1}{4}$ in. mesh.
2d size, that which passed $\frac{1}{4}$ in., but remained on $\frac{1}{8}$ in.
3d size, " " $\frac{1}{8}$ in., " " $\frac{1}{20}$ in.
4th size, " " $\frac{1}{20}$ in., " " $\frac{1}{40}$ in.
5th size, " " $\frac{1}{40}$ in.

The first three sizes were put each separately on the jig. In this case the operation was made easier by the iron pyrites in the ores, which being intermediate in specific gravity between galena and blende, formed a bright thin layer between the other two minerals. It was of great importance that as little blende as possible should be mixed with the galena, as it would be in the way in the future work, but it did not make as much difference whether the blende was mixed with a little galena or not. The iron pyrites did not harm either part. The course I followed was this: After having skimmed off the gangue I skimmed off the blende and the layer of pyrites, leaving only the galena. Some of the galena was taken with the blende to make sure that no blende remained in the galena. This accounts for the rather high percentage of lead found in the blende part. The ore was put in so as to be about

three inches deep for the larger sizes, and about two inches for the smaller. I gave about one hundred strokes for each portion, and the separation appeared good in each case. The jig was a $\frac{1}{30}$ in. sieve placed in a large tub of water, and suspended to a spring board above. A good deal of ore which had not passed in the dry sifting went through the $\frac{1}{30}$ in. sieve. This was collected and treated on the shaking table, as was also the $\frac{1}{40}$ in. product and that which had passed the $\frac{1}{40}$ in. sieve. The principle of separation in the shaking table is to throw the ore up an inclined plane by means of a jerk at regular intervals, while water, between the jerks, causes it to go down. By regulating the stream and the slope of the table, the water may be made to carry off the blende and gangue, leaving the galena on the jerking table.

There were three parts from the jig, viz.: — galena, blende, and gangue portions. The gangue portion having been jigged several times to get all the mineral part out, was then put aside and not worked any more. The ore from the shaking table was also divided into three parts, viz.: — a galena portion, a mixture of gangue and blende, and a slime which was not worked.

The weights from the jig were: —

Gangue portion	20 lbs. 7 oz.
Blende portion	48 " 0 "
Galena portion	63 " 6 "
	131 lbs. 13 oz.

The weights from the shaking table were: —

Slime	2 lbs. 14 oz.
Blende and gangue portion	13 " 0 "
Galena	29 " 4 "
	45 lbs. 2 oz.

Samples were taken of the three portions from the jigs and two portions from the shaking table, and they were analysed for lead and zinc, and assayed for silver, with the following results: —

GALENA FROM JIG.

Lead	70.36 per cent.
Zinc	0.75 "
Silver	0.103 "

ZINC BLENDE FROM JIG.

Lead	14.27	per cent.
Zinc	20.75	"
Silver	0.035	"

GANGUE FROM JIG.

Lead	6.28	per cent.
Zinc	0.88	"
Silver.	0.013	"

GALENA FROM SHAKING TABLE.

Lead	62.65	per cent.
Zinc	1.90	"
Silver	0.087	"

RLENDE AND GANGUE FROM SHAKING TABLE.

Lead	14.15	per cent.
Zinc	10.89	"
Silver.	0.035	"

The galena had now been separated from the rest of the ore and after drying and crushing to $\frac{1}{10}$ in., the different parts weighed: —

Galena hand picked	31 lbs. 6 oz.
" from jig	63 " 6 "
" from shaking table	29 " 4 "
Total Galena	124 lbs. 0 oz.

An analysis of this gave: —

Lead	69.35	per cent.
Silver	0.106	"

(The per cent. in this case were calculated from the aliquot parts.)

This galena was roasted in a reverberatory furnace at a heat just below the fusing point of galena. The object of the roasting is to drive off the sulphur and this would be retarded by the caking of the galena. The ore is stirred constantly to expose every part of the ore. In this case, I failed to avoid caking by fusion, but the lumps thus formed were broken up as much as possible by the stirrer. The roasting went on for three and one-half hours, at the end of which time no more sulphur came off from the ore. A sample was taken at the end of two hours' roasting, also at the end of the roast, and they were analyzed for sulphur with the following results: —

Sulphur after 2 hours roast	8.61 per cent.
" " 3½ "	8.15 "
Before roasting, the hand picked galena contained	16.33 "

The roasted galena was then analyzed with the following results: —

Lead	59.28 per cent.
Silver	0.11 "
Weight roasted Galena	113 lbs. 11 oz.

The great loss of lead was in the lead fumes which went up the chimney during the roasting. The theoretical amount of lead to be got from the roasted ore was then 67 lbs. 6 oz., and the silver 0.125 lbs.

A flux was calculated for the roasted galena according to the percentage of sulphur and lead in it, which consisted of 52.4 lbs. magnetite and 4.9 lbs. charcoal dust, to 100 lbs. of ore. 60 lbs. of ore were mixed with the fluxes in the above proportions; but, one charge of ore of 15 lbs. having been tried, it was found by its action on the crucible, that there was too much iron for the amount of coal, and consequently 4 lbs. charcoal dust were added to the remaining 45 lbs. The result proved more satisfactory. The iron is put in to reduce the sulphide of lead to lead and to take up the siliceous impurities. The charcoal reduces the oxides of lead and iron that are formed. When the 45 lbs. ore gave out, each charge of 15 lbs. of ore was mixed with 2 lbs. charcoal and two thirds as much magnetite in proportion, as before. The estimate of magnetite was at first too large on account of an error in the estimation of the per cent. of sulphur in the roasted ore, which was caused by an impurity in one of the laboratory reagents.

The number of charges fused was 8, out of which, one charge went through the crucible and about 4 lbs. of metallic lead were lost. 7 of the 8 charges had 15 lbs. ore, and the 8th had 8 lbs. 10 ozs. The charges were smelted by being first well mixed with the fluxes, and then put into a black lead crucible and fused at a bright red heat from two to three hours until the whole mass was perfectly liquid. The charge was then poured into a mould. Great care had to be taken to heat the black lead crucible very gradually, as they are liable to crack if this is not done.

The result of the smelting consisted of the slag, matt and

51 lbs. 6 oz. crude lead. If the 4 lbs. lost by poor crucible were added to this it would give: —

Total lead obtained (about)	55 lbs. 6 oz.
Theoretical amount of lead in ore	67 " 6 "
Loss in slag and matt	12 lbs. 0 oz.

This would show that between 17 and 18 per cent. of the lead had gone into the slag, matt and fume.

The crude lead was refined by fusing it, to drive off the sulphur, and by sweating it. This gave 47 lbs. 14 ozs. of refined lead, which was assayed for silver with the following result: —

Per cent. silver obtained in lead . . .	0.21
Weight silver	0.101 lbs.
Loss on theoretical amount	18 to 19 per cent.

The lead was melted in a cast iron pot and heated to driving. 2 lbs. 6 oz. of zinc (5 per cent. of the amount of lead) were melted in a black lead crucible, and just as oxide of zinc was beginning to be formed and to burn, it was poured into the molten lead and the bath having been thoroughly stirred, the zinced lead was poured into ingots. The process of extracting silver out of lead, by means of zinc, is called "Parke's process" after the name of its inventor. It depends on the fact that when zinc and silver lead are mixed at a strong red heat nearly all the silver goes with the zinc.

It consists of 5 stages. 1st, Zincing the lead. 2d, Sweating off the pure lead from the argentiferous zinc lead, owing to the lower fusing point of pure lead. 3d, Refining the lead, thus obtained. 4th, Removing the zinc from the argentiferous zinc lead by distillation. 5th, Cupelling the argentiferous lead. The first stage I have already described. The ingots were then put on the sweating furnace, and the pure lead melted from the zinced lead. The lead thus melted was refined by driving off the zinc, and it was then assayed for silver, giving 0.0038 per cent. Ag. Before refining, the weight of the lead was 38 lbs. After refining, it was 34 lbs. 5 oz. The loss was due to the escape of lead fumes as well as to the driving off of the zinc. The argentiferous zinc lead was then refined by distilling off the zinc at a bright red heat in a black lead crucible.

Charcoal was put on top of the molten liquid to reduce the litharge formed while the oxide of zinc burned off. The time taken to distil the zinc was two hours. The argentiferous lead was then poured into ingots and weighed 9 lbs. 1 oz. A sample of this was taken and assayed 0.855 per cent. Ag. The argentiferous lead was then cupelled in a cupel furnace. The furnace was first heated to a bright redness and the ingots of lead were put in one by one, and as they oxidized, the litharge was poured off. The ingots were put in 3 hours 30 minutes after the fire was started, and the button blicked 2 hours 23 minutes after the lead had been put in. The silver button weighed 22.7782 grs. or .0502 lbs. instead of the theoretical .0782 lbs. which had been put on the cupel.

The cupel was made by mixing 15 lbs. of bone ash, 2 oz. fire clay and 6 oz. litharge.

		Per cent. Ag.	Wt. Ag in lbs.	Loss Ag since last operation.	Per cent. Pb.	Weight Pb.	Loss Pb since last operation
124 lbs.	Galena	0.105	.1314		69.35	86 lbs.	
118 lbs. 11 oz.	Roasted Galena	0.11	.1252	.0062	57.28	67 lbs. 6 oz.	18 lbs. 10 oz.
51 lbs. 6 oz.	Crude lead	——	——	——	100.0	51 lbs. 6 oz.	16 lbs. 0 oz.
4 lbs.	Loss by accident	——	——	——			
47 lbs. 14 oz	Refined lead	0.21	.1005	.0247	99.8	47 lbs. 14 oz.	3 lbs. 8 oz.
9 lbs. 1 oz.	Argentif. lead	0.855	.0782	.0795	99.2	9 lbs. 1 oz.	43 lbs. 6 oz. 4 lbs. 8 oz.
34 lbs. 5 oz.	Comm'l (refined)	0.0038	.0013	.0210	100.0	34 lbs. 5 oz.	
0502 lbs.	Silver button	100.0	.0502	.0293	.0	0	9 lbs. 1 oz.

Lead obtained. 34 lbs. 5 oz

Silver obtained .0892 Total lead in ore, 86 lbs. 0 oz.

.1314 total silver in ore.

Silver in the ore	0.1314 lbs.		
Lead in the ore	86 " 0 oz.		
Loss from roasting		18 lbs. 10 oz.	0.0062 lbs.
Loss from smelting		12 " 0 "	0.0247 "
Loss by accident		4 " 0 "	
Loss from refining		3 " 8 "	
Loss from zincing, Sweating and distilling, Loss from refining lead, with silver taken out		4 " 8 "	0.0223 "
Loss from cupelling		9 " 1 "	0.0280 "
Lead obtained		34 " 5 "	
Silver obtained			0.0502 "

The zinc portion was carefully worked, roasted, ground with salt, and re-roasted and amalgamated, but owing to an accident at the last moment the yield of silver was greatly reduced. In the place of .021 of a lb. of silver which the ore contained, only .008 were extracted.

Working of an ore of Silver and Lead from Newbury, Mass. Abstract by Wm. H. Shockley.

This thesis describes the situation of Newbury, the story of the discovery of the mine, a mention of the gneiss rocks in which it is found, and quotations of analyses of the vein stone. The ore that was worked was float ore from the Chipman Lode. The ore presented the usual appearance of a float ore being covered with oxide of iron and various decomposed minerals. An examination was made of the mineral species, and the following were detected. Galenite, quartz, siderite, limonite, hematite, pyrite, chalcopyrite, tetrahedrite, malachite, azurite, zinc blende, crocoisite, kaolin. The principal mineral constituents are galena, quartz and pyrite.

A partial analysis of the ore gave: —

		Calculated Minerals.		
			No. 1.	*No.* 2.
Silica	16.18	Quartz,	13.61	13.61
Lead	45.39	Sphalerite,	1.21	1.05
Copper	1.33	Chalcopyrite,	3.84	1.65
Zinc	.81	Pyrite,	14.81	15.31
Iron	8.34	Kaolin,	5.17	5.17
Alumina	2.23	Siderite,	.53	.53
Sulphur	16.70	Galenite,	52.68	52.55
Carbonic acid	.20	Limonite,	5.10	5.72
Ferric oxide	5.10		96.95	Tetrahedrite, 2.15
Silver	.20			97.74
Gold	.002			
Undetermined (As, etc.),	3.52			
	100.00			

No. 1 is calculated directly from the ore analysis. Now if we assume the galena to have 19 per cent. Ag. (and this assumption is warranted by the assays) we shall have the galena in the ore (52.41 per cent.) taking 10 per cent. of the silver,

and if the remainder be assumed to constitute the 4.65 per cent. of the tetrahedrite, (which the assay shows to be the case) we shall have the basis for the result given in the second column.

The value of a ton of this in currency is (gold, 1.15) : —

207 lbs lead,	$54.46
58.32 oz. silver,	86.81
.58 oz. gold,	13.89
	$154.96

An examination was made of the various qualities of galena to see how the silver was distributed. The results of the assays are : —

	Per cent.	oz.	
Coarse galena from 30′ below surface,	.35	102	$131.65
Medium galena from ore,	.09	29.16	37.61
Fine " "	.22	65.90	85.01
Tetrahedrite "	4.65	1357.19	1750.77
" from Chipman Shaft	2.30	670.68	865.17

Other tetrahedrites have varied from $500–$1300.

DETAILS OF WORKING ORE.

Weight = kilogrammes.

The ore was in large lumps weighing from 10 to 30 kilos. The first operation was to break up these lumps and pick out the ore to be worked. At the same time pieces were picked out and examined for the minerals.

The weight of the whole lot was 816.41 kilos., the amount picked out 324.97 kilos., this being as near as possible fair sample of the whole. The ore was passed through a small Blake crusher and then through rollers; these operations were to crush the ore so it might be fit for roasting. The ore was then sampled, passed through a $\frac{1}{20}''$ sieve, the portion remaining on the sieve was rerolled until it was judged to be about $\frac{1}{20}''$. The loss in crushing was .34 kilos., the sample taken out weighed 6.40 kilos., so that the ore now weighed only 311.13; the loss of 7.64 kilos. was due to sifting, rolling, and to the fact that some of the ore was overlooked and remained behind. The ore was divided into eight charges, each of 39 kilos.; it was roasted in two reverberatory furnaces, each charge being roasted four hours. A sample was taken at the end of two hours, and also

when the charge was drawn; these samples were analyzed for sulphur; the results of these analyses will be found farther on.

After the ore was roasted it was put in the larger of the two furnaces and agglomerated. A sample was taken of this agglomerated ore and analyzed so as to furnish data for calculation of slag, etc. The object of agglomerating the ore, was to make it strong enough to stand the pressure of the fuel and fluxes.

The percentage of sulphur before roasting the ore was 16.70 per cent. The following table shows the per cent. of sulphur removed by roasting.

No. of the charge.	*No.* 1.	2.	3.	4.	5.	6.	7.	8.
Sulphur after 2 hours roast'g,	7.36	7.85	6.60	7.09	not deter.	10.13	5.70	9.91
Sulphur after 4 hours roast'g,	4.18	6.23	4.90	4.97	not deter.	4.85	4.36	5.77

The ore after being agglomerated weighed 251.5 kilos.; a sample was taken and a partial analysis made, so that there might be data enough to calculate the amount of fluxes to be used. After these calculations were made, the ore was run in the blast furnace. The details as to the run will be found in the tables on pages 22 to 30 inclusive. A slag from the Revere Copper Works was used to start the furnace with. It was found after running some time that the proportion of flux and ore was too great for the fuel, so the charge was altered by taking only three-fourths the amount of ore and flux to the fuel; after this the furnace worked well.

The calculations were to have a basic slag; the fluxes used were puddle cinder and limestone; the exact composition of the puddle cinder was not known at the time of the calculation, but it was judged that it contained about 20 per cent. SiO_2 to 70 per cent. FeO, and acting on this supposition the following charge was calculated:—

40 lbs. ore.
25 lbs. puddle cinders.
3 lbs. limestone.
3 shovels coke.

This charge was afterwards changed to

30 lbs. ore.
18¾ lbs. puddle cinder.
2½ lbs. limestone.
3 shovels coke.

This change was made in order to bring the layers of fuel nearer together.

The analysis of the puddle cinder afterwards made and of the roasted agglomerated ore are below.

Puddle Cinder.		*Ore.*	
FeO,	70.62	FeO,	17.11
SiO_2,	15.43	SiO_2,	18.47
Al_2O_3	9.42	Al_2O_3	2.57
		S,	3.27

Now this gives in each charge the following amounts:—

	SiO_2	Al_2O_3	CaO	FeO	S
Ore,	7.39	4.03	0	6.84	1.31
Puddle cinder,	3.86	2.45	0	17.65	0
Limestone,	0	0	1.68	0	0

After allowing sufficient iron to remove the sulphur as FeS the calculation of the per cents. of the components in the slag is as follows:—

	SiO_2	Al_2O_3	CaO	FeO	Pb
Calulated Slag	29.56	9.23	4.41	56.77	0
Actual Slag, as obtained,	30.54	9.71	4.66	48.86	2.44

The discrepancy between the calculated slag and the slag actually obtained is due to two causes; viz., the dissolving of silica from the bricks and the charging of the Revere Slag at sundry times during the run. The analysis of the Revere Slag is:—

FeO, 41.86
CaO, 9.96
SiO_2, 37.00
Al_2O_3, 6.21

The furnace was started with Revere Slag, and the first twelve kettles consisted of this and were laid aside. The remaining products were slag and lead, and a small quantity of iron matte. The lead and slag were separated, and gave 220.42 kilos. slag, 82.54 kilos. lead. There was 90.71 kilos.

foul slag, *i. e.*, slag containing too much metallic lead to be thrown away, consisting of nozzles, furnace bottom, and bits of the total slag with adhering lead. This slag was crushed and sifted; the part remaining on the sieve, jigged; the portion going through the jig treated on the Spitz-lütte. The products from these operations were smelted, and 8.16 kilos. of lead obtained; this was put with the cake lead, increasing its weight to 90.70 kilos. From each cake as it was broken up, a piece of pure slag was picked out; these bits were crushed and sampled and an analysis made of the sample. It is to this analysis that I have reference when speaking of slag, page 20. An analysis was also made of the total slag — it gave 290 per cent. Pb, *i. e.*, 6.39 kilos. Now the amount of lead that should have been obtained is 148.95, the amount that was obtained is 90.71 k.; this with the amount in the slag = 97.10 k. or 67.45 per cent., thus showing a loss in the operations of smelting and roasting of 32.55 per cent.

I am not able to state how much of this loss is due to roasting nor how much is due to smelting. The loss is probably caused by fumes, and it must be caused by volatilization, because all the products have been assayed for lead and none has been found, save as stated.

The cake lead was now refined. It was attempted to do this in a crucible by skimming, but this was found impracticable on account of the great impurity of the lead. The lead was, for the foregoing reasons, run into ingots and sweated. The resultant lead, 62.5 kilos. was quite pure and was all ready to be zinced. This lead was assayed for silver and gave .448 per cent. or 280.31 grms Ag.

There was formed during this process of refining, quite an amount of skimming. There was also quite an amount of dross left on the sweating furnace. Both of these compounds contained a large amount of copper. They were smelted and from the smelting was obtained 7.7 kilos. lead, containing .341 per cent. Ag. or 26.26 grammes; and 12.70 kilos. lead with .332 per cent. Ag. or 42.16 grms. The 7.7 kilos. was from the

skimmings, the 12.70 k. from the dross. The loss of lead by this operation was 7.74 kilos.; the loss of silver cannot be told.

The lead obtained from the smelting of the skimmings and dross was very rich in copper; now it was desired to remove the silver from the lead by zincing. Copper is a detriment to this process and therefore it was advisable to remove it (*i. e.*, the copper). The method devised for doing this depends on the greater affinity of sulphur for copper than for lead. If galena and copper are heated in a reducing atmosphere, lead is set free and copper matte (sulphide of copper) is formed. Taking advantage of this fact, the copper was removed from the lead. The maximum amount of copper that could be present, being known, enough galena was added to change this to sulphide, also a sufficient amount of pyrrholine, magnetic pyrites, was added to make a matte of the formula (Cu_2S FeS) and the fusions were made. The results were very good, a matte rich in copper and a lead very free from copper were obtained.

Weight of lead, 15.25 kilos.
" " matte, 5.90 "

The subsequent operations of desilverizing the lead, cupelling to fine silver and recovering the lead from the various products, yielded very unsatisfactory results, owing to defects in the cupel furnace and other apparatus.

Treatment of a Silver Ore from Silver Islet, Wood's Location, Ontario, Canada, Lake Superior. Abstract by the author, H. L. J. Warren.

The ore was of low grade, the assay value being only about $10 to the ton. The silver was present in three modifications, native, sulphuret, and argentiferous galena. In securing a good concentration of the valuable minerals was found the main difficulty in its treatment. These were present in such minute particles, and the gangue was of so refractory a nature, consisting chiefly of calcite with a small amount of heavy spar, which, after the ore was passed through a $\frac{1}{16}$ mesh, were

reduced to a large extent to a fine powder, which so completely enveloped the ore itself when treated on the jig, or bump table, that no satisfactory separation could be made. After a number of fruitless attempts the bump table furnished two products, a slime, and the remainder of the ore. These were then treated by the spitzlütte of Rittenger, which in the end gave quite satisfactory results. The following table shows the final products both those of value and the waste. It explains itself.

Rich concentrated mineral.	*Weight in kilograms.*	*Percent. of silver.*	*Value of silver.*	*Waste products and slimes.*	*Weight in kilograms.*	*Per ct. of silver.*	*Value of silver.*
Original ore	81.5	.0286	$0.03	Original slime	18.6	.013	$0.006
Product A.	.354	.2361	0.001	Spitzlütte slime	5.7	.005	.011
" B.	.005	1.2503	.032	2d bump table slime	1.3	.016	.008
" C.	.081	.8751	.028				
" D.	.162	.0935	.006				
" E.	.109	.310	.013	Product H.	8.7	.008	.027
" F.	1.431	.307	.175	" K.	2.8	.007	.008
" G.	.617	.164	.040	" M.	3.4	.010	.014
" H.	.051	.473	.009	" P.	4.5	.009	.016
" I.	1.383	.096	.053	" R.	6.2	.011	.027
" J.	.810	.197	.064	" W.	3.8	.019	.029
" K.	.741	.009	.029	" V.	4.9	.017	.025
Total	6.105		0.51	" X.	3.6	.020	.029
Totalsmelt'g pro.	6.105	.241	.59	" Z.	3.9	.009	.014
Accounted for	77.8		.91	" D.	4.3	.008	.013
Loss	3.3		.82		71.7		0.310

Working of an Ore from Middletown, Ct., by Wm. R. Webster.

(No abstract furnished.)

DEPARTMENT OF ARCHITECTURE.

Design for the buildings for a City Water Works. Abstract by the author, Amos J. Boyden.

The problem for solution in this thesis required designs for an Engine House and Stand Pipe Tower in the public park of a small city, together with such other buildings, or architectural adornments, as would be conducive to the convenience or pleasure of visitors to the park.

In the design, the plan of the engine house resolves itself into three parts, as follows: —

1st, that part devoted to the government of the works, occupying the front of the building, and two stories in height. The principal rooms on the first floor of this part are, an office with adjoining ante-room, a visitors' room, a commissioners' room and a lavatory. These rooms are ranged along the main entrance hall, from which a stairway leads to the second floor, and to the basement.

On the second floor are five large well lighted rooms and a bath room. This floor is designed for the use of the resident engineer and his family.

2d. Part second of the building consists of the engine room and an adjoining boiler room, the floor of which is four feet lower than that of the engine room. A gallery runs around the engine room, access to which is gained from the first landing of the stairs from main hall to second floor.

3d. Wings one story in height extend from the engine room and from the boiler room to the retaining wall in the hill side, into which they run several feet. The boiler room wing is designed for a coal house, and is so situated that the coal may be dropped from the carts directly into the bins.

The engine house wing is divided into a machine shop and a carpenters' shop.

A chimney shaft 106 feet high is situated near the boiler room, on the axis of the plan.

The water is to be forced a distance of about 600 feet to the stand pipe tower, which is 160 feet high, 24 feet square at the base, and 20 feet square at the top. Adjoining the tower is a small gate house.

The most architectural building in the park is a refreshment hall, containing waiting rooms for ladies and gentlemen, a hall for pleasure parties, and various smaller rooms shown on the accompanying plans. As in the engine house, wings extend to the retaining wall, the flat roofs of which give access to the

hall, while the rooms below may serve as ice house, and cellar, and the well lighted part as kitchen.

The required thickness of the retaining wall, 24 feet high, was calculated and found to be 7.65 feet at the base. The roof trusses of the engine house are large primary trusses, composed of two wooden rafters, connected by an iron tie rod, the rafters being supported by three small secondary trusses. The stresses in the various pieces of one of these trusses have been calculated. The required sectional area of the rafters was found to be 29.06 square inches.

Calculations were also made for the required indicated horse power of the engines.

DEPARTMENT OF CHEMISTRY.

Anthracene Pressings. Abstract by the author, Leonard P. Kinnicutt.

My thesis can be divided into the following principal topics:

1. Historical notice of the discovery of Anthracene.
2. Description of the manufacture of Anthracene.
3. Anthracene Pressings.
4. The partial separation of the Hydro-Carbons, which compose these pressings, into four principal products, by means of the difference of their solubility in alcohol.
5. The determination of Anthracene in the four products, by means of Suck's test.
6. Forming crystals, by treating each of the four products with a solution of picric acid.
7. The finding of Phenanthrene in the pressings.
8. The Phenanthrene colors, and the value of Phenanthrene in the future.
9. The value of a quantitative test for Phenanthrene.
10. Testing the different methods by which it would seem possible to determine Phenanthrene quantitatively.

11. The comparison of the different methods, and the reasons for changing Phenanthrene into Phenanthrene Quinine, for the determination of Phenanthrene in this investigation.

12. The determination of Phenanthrene in the four different products.

13. The general result of my work.

DEPARTMENT OF PHYSICS.

Report of a series of experiments made with a Holtz Machine. Abstract by the author, S. J. Mixter.

1. An account of previous measurements of electrical machines by Moscart and Rossetti.

2. The machine used in my experiments was made by Mr. E. S. Ritchie. It has a single plate 2 feet in diameter. The motor was a small high pressure steam engine, having a cylinder 2 inches in diameter, and $3\frac{1}{4}$ inches stroke. The work was measured by a form of dynamometer first used by Huyghens; the principle involved is, that the work transmitted through a belt equals the speed of the belt into one-half of the difference in the weights which balance on the two sides of the driven pulley. The strength of the current was measured by a galvanometer made from the secondary coil of a resistance coil, having a resistance of 6,313 ohms, and whose constant was accurately determined.

3. Various series of experiments were made to determine the work converted into electricity.

(*a.*) Amount of work required to run the machine when discharged and charged, varying the length of the spark.

(*b.*) On the absolute strength of this current, and the amount of work converted into electricity. From the results obtained the electromotive force and interior resistance were calculated.

Curves representing the several series of observations are given.

The Empire of Austria. By Wm. A. Prentiss. Abstract.

Area and physical features; Component parts of the Empire; Ethnology; Vegetable and mineral products; Statistics of Commerce; Early history and growth of the Empire; Present constitution and government; Austria since Sadowa; Present position and prospects; List of authorities referred to

Switzerland. By James Liddell Arnott.

(Abstract not received.)

THE DEPARTMENT OF ARCHITECTURE.

The founders of the Institute of Technology included Architecture among the branches first to be provided for, and a professorship in this department was established and the chair filled on the opening of the school in 1865. This appointment was made and accepted, however, on the understanding that the work of instruction should not be begun until proper apparatus had been collected, and opportunity given for studying the methods of professional instruction employed in architectural schools abroad. In the spring of 1866, accordingly, Professor Ware asked leave of absence and remained abroad until the end of the following year, examining the foreign schools, consulting personally with the architects in charge of them or with others who were familiar with their working, and collecting casts, photographs, drawings and other materials of instruction, which the generosity of some friends of this undertaking had given him the means of purchasing.

THE ARCHITECTURAL MUSEUM.

The collections thus begun have gradually increased in amount and value until they will compare for interest and for serviceableness with those anywhere put at the disposition of architectural students, supplemented as they are by the collections of the Museum of Fine Arts, established in the immediate

neighborhood, and by the treasures of the Boston Public Library, whose trustees, as well as those of the Boston Athenæum, have done everything in their power to increase the facilities for their use. Some unusually favorable circumstances rendered these collections, even at the outset, much more extensive and valuable than was reasonably to be looked for, especially in respect of mediæval sculpture and carvings, and architectural drawings. A large and almost unique collection of casts from Lincoln and Southwell minsters, fortunately fell into our hands, which was afterwards supplemented by considerable additions from French Gothic work of the same period. To the generosity of the late Mr. Ernst Benzon, formerly a merchant of Boston, we were indebted for an unusually good collection of school drawings, made by students in architecture at the École des Beaux-Arts in Paris, and at the French Academy in Rome. These have been added to, as circumstances have favored, until we now have a series of works, illustrating every stage of study, which for completeness and extent, as well as for intrinsic merit and usefulness as examples to the student, is hardly to be found elsewhere, even in the ateliers of the École des Beaux-Arts itself. These collections were largely augmented by the kindness of many gentlemen, mostly architects, who, both in England and on the Continent, as well as on this side the water, evinced a kindly interest in our undertakings and gave not only photographs of their works, but tracings and lithographic copies of working drawings, with specimens of specifications, estimates, bills of quantities, and various forms of business papers. We are under special obligations to Mr. Waterhouse, Mr. Withers, Mr. Norton, Mr. Nash, Mr. Rickman, Mr. Keeling, Mr. Edis and the late Mr. Papworth, in London, to Mr. Bryce in Edinburgh, and the late Mr. Thomson in Glasgow, and to M. Viollet-le-Duc, M. Charles Garnier and M. Lesoufachér in Paris. M. César Daly, a constant friend of this country, presented to the department his valuable work illustrating the domestic architecture of the Second Empire, and the French Minister of Public Instruction,

M. Duruy, acting through our minister, General Dix, put at our disposition a number of illustrated works relating to the architectural history of France, among which are the magnificent monograph of the Cathedral of Chartres, and the two volumes entitled the "Statisque Monumentale de Paris." The Institute of Scottish Architects, and the Architectural Publication Society of London, added a number of valuable publications, while the Royal Institute of British Architects, not only presented us with a complete set of their valuable and interesting Proceedings, but were good enough to put us upon their books, so that we have since continued regularly to receive the papers they have published. The *Societé Centrale des Architectes* in Paris also send us the papers they from time to time put forth. This beginning of a library was largely added to in the summer of 1872, by means of a fund specially collected for the purpose, so that the books on the shelves now number three hundred and fifty volumes, most of which are excellently suited to the wants of the students and are constantly consulted by them. These books, as well as the photographs, prints and drawings, which also have been largely added to from year to year, are at all times accessible to the students, and are freely used by them. It has not been found that this freedom has been abused to the injury of the collections, and the advantage to the school is so great that it is worth while to run a considerable risk, rather than limit their serviceableness.

Besides the casts, photographs, books and drawings, the most noticeable thing in the collections is the stained glass, a part of which has been purchased, but it is in great part the gift of the makers. It is arranged on four movable screens and comprises work by Messrs. Morris & Co., Lavers, Barraud and Westlake, Heaton, Butler and Bayne, Clayton and Bell, Cottier & Co., J. T Lyon, and G. E. Cook of London, and Messrs. Cook, and McPherson & Co., of Boston, besides some fragments of mediæval work.

A detailed memorandum of these collections is given in the Appendix.

COURSE OF INSTRUCTION.

The Museum was arranged during the spring and summer of 1868 and the department opened with four pupils, in October of that year. This number has gradually increased until there are now thirty-two students in attendance, ten of whom are regular students in the Institute, pursuing a four years' course of study, and taking architecture in addition to the mathematical and scientific work pursued in other departments of the school. The other twenty-two are special students, pursuing a two years' course which is confined to the strictly professional work. The special students, however, give all their time to their studies, the same as the others; the plan of having students spend part of the day in architects' offices and part at the school was tried for a year or two, but it did not prove satisfactory in any respect, and is now given up.

This professional work consists chiefly in successive exercises in architectural drawing and design, introductory to which are given lectures, with practical exercises, in shades and shadows and in the elements of architecture, beginning with the orders and giving simple rules for laying them out, and going on to doors, windows, staircases, arcades, vaults, domes and roofs. The history of architecture is then taken up, the Greek and Roman history first, which is gone over with every class as soon as they have completed these elementary studies, followed by the history of the Mediæval and of the Modern styles, which for convenience are taken up in alternate years. The more advanced students have lectures once a week on the theory of architecture, and upon the arts specially related to building, such as stained glass, mosaic, color, carving, etc. Once a week throughout the year is a lecture upon specifications and working drawings; carpentry and its related subjects being taken up one year and masonry, etc., the next, so that the whole course occupies two years. This subject is necessarily treated in a somewhat superficial manner, since it is the object of the department to give the instruction that cannot be obtained in

architects' offices, leaving students to learn what can there best be learned during the term of their service as draughtsmen. But the rapid survey these lectures afford is found to be worth the small amount of time it consumes, serving as a sort of review of the subject to those who are already familiar with it, and as a serviceable preparation for office work to others. To both it is useful, as giving a more comprehensive view of the subject than office experience is apt to afford.

Instruction is also given in Perspective, Descriptive Geometry, Stereotomy and Free-hand Drawing. The practice in architectural drawing begins with elementary exercises in india ink, with the pen and with the brush, followed by exercises in the use of india ink and color, beginning with architectural details or fragments on a large scale, and going on to plans, elevations and details, first copied from books, and, the next year, drawn from actual measurement of buildings in the neighborhood of the school. Drawings have, in this way been made of King's Chapel, the First Church, the Central Church, Emmanuel Church and some others, the spires of Park Street Church, the Old South, Hollis Street Church, and Christ Church in Salem Street, of the principal railway stations in Boston, and of a number of dormer windows and doorways, and details of cast and wrought iron work and of ornamental brick work.

The practice in design begins with simple problems intended as practice in the use of the orders, and goes on gradually to the higher class of monumental work, and to buildings of complicated and difficult plan. Among the subjects of these exercises have been the following: — A Porch to a Private House, a Drive-way, a Campanile, a Peristyle, a Staircase under a vault or dome, the employment of four (or six) columns, a Boat House and Billiard Room, a Pavilion between two Bridges, a Monumental Bridge, the restoration of a Pompeian House, a Lamp Post, a Fountain, a Chimney-Piece, a Vestibule, a Small Museum, a Memorial Library, a Memorial School House, a Railroad Station, an Artist's House, a Monumental Chapel, a Catholic Church, Water Works in a Pub-

lic Park, an Iron Kiosk, a Casino, a Dwelling House, a School of Chemistry, a School of Medicine and a School of Architecture. As the class become more advanced, details upon a larger scale are often required. The time allowed for these problems varies from a couple of days to a couple of months according to the difficulty of the work, the experience of the students, and the number and size of the drawings required. Each class do ten or twelve of these exercises in the course of the year.

The subjects, as will be noticed, are most of them somewhat out of the line of daily experience. More practical problems would require for their solution more practical experience than such classes as these can possibly have had, involving for their solution numerous considerations of detail, which it would not do to slight, but which students in the beginning of their studies are not prepared to entertain. Work of this kind, on the other hand, while it taxes their powers to the utmost, both in the execution of the drawings and in the design, does not demand, for its satisfactory performance, any greater resources either of knowledge or skill, than they have at command. Besides, its remoteness from daily use and observation, not only stimulates the imagination and fancy, but necessitates the study of the books and of the work of the best masters.

The classes are made up, besides the regular students of the Institute, of boys just from school, of mechanics wishing to become draughtsmen in offices, of draughtsmen who have already had office experience and who wish to learn what an office does not give, and of graduates of colleges who desire to enter upon their profession in the most rapid and intelligent way. It is not possible to lay down a strict course of study that shall equally meet all the wants and occupy all the time of persons varying so much in personal training. But the special work of the school is new to all alike and serves equally well for all as their chief interest and object of study. Moreover, the largeness of the company is an advantage, and all would suffer if they were broken up into smaller groups. The work done is equally in-

structive to all, whether the result is more or less excellent in conception or in execution. In point of fact, although at the beginning of the year there is great difference in the work, by the end of the year it is often hard to tell the work of the beginners from that of the more experienced hands. Meanwhile the resources of the establishment are open to all, and as much is done, and as much is learned in volunteer work, especially tracing and sketching, not to speak of reading, as is accomplished under the requirements of the programme. The students learn much more than they are taught, and what they thus teach themselves is not likely to be forgotten.

ARCHITECTURAL PROBLEMS.

December 1.

An Open Porch before a Private House.

The house to which this porch or portico belongs is supposed to be situated in the principal street of a city, the steps of the porch descending to the sidewalk. The upper platform or landing is to be raised nine steps from the sidewalk, the threshold of the front door forming a tenth step. This platform is to be about one hundred square feet in area, more or less. The steps must not be more than six or seven inches high, nor less than twelve inches wide. Balustrades must not be more, nor much less, than three feet in height. The whole is to be constructed of stone, and is to conform in its proportions and its details to the regular rules for the Five Orders. The whole problem is to be regarded as an exercise in the practical application of those rules. If arches are used, they will accordingly be semi-circular.

Required: *A Plan*, showing the platform, steps, sidewalk, and the beginning of the vestibule of the house, the horizontal section being taken at half the height of the columns, and cutting through the front wall of the house and the front doorway.

An Elevation, showing the front of the porch towards the street, and the main doorway at the back of the porch.

A Section, taken through the middle of the porch, and extending to the vestibule.

All these drawings to be made on half an Imperial sheet of Whatman paper, stretched, to a uniform scale of a quarter of an inch to the foot, and finished in pencil, with the shadows cast in India Ink. Color may be added, if desired. The elevation will be set above the plan, on the same

vertical axis, and the section at the side of the elevation. A side elevation may be added, if desired.

This sheet of drawings must be handed in on Monday, December 8.

A Temple Tomb. *December 8.*

It is the custom in some countries to erect over a grave or tomb a small temple or oratory, just large enough to cover it, containing an altar where a single mourner may offer prayers for the dead.

It is required to design such a structure, making it in the form of a small Grecian temple, with two columns, *prostyle*, all the details being Greek rather than Roman in character. The plot of ground is supposed to measure six feet by twelve.

Required: *A Plan, Section, and two Elevations*, on a uniform scale of half an inch to the foot, with details one-eighth full size, all on an Imperial sheet.

A Drive-way. *December 9.*

The object of a Drive-way is almost the same as that of a porch; it differs only in that it serves as a shelter, not only to pedestrians, but to those who come in carriages. The proposed structure would be part of a rich private house erected on a public square. It must be sufficiently large for a carriage to pass freely under, and at the same time give access to the main hall of the house. The plan must be so arranged that pedestrians need not meet the carriages, in order to avoid accidents. The greatest dimensions of this structure must not exceed 500 square feet. The doorway must be about four steps above the roadway, with proper steps and platforms between.

Required: *A Plan, Section* and *Two Elevations*, on a uniform scale of one-eighth of an inch to the foot, to be drawn in pencil, shaded with India ink, with or without color, the sections to be tinted in carmine, the plan in vermilion, and the whole to be drawn upon a half-sheet of Imperial Whatman, the top of the paper being the narrowest, and to be cut up to a uniform size of 21 inches by 14 inches, with a border within.

The drawings will be handed in on Monday, December 16, at half-past three o'clock in the afternoon. The adjacent parts of the house may be indicated.

A Portico in a Garden. *December 17.*

This little building is supposed to be erected at the extremity of a garden attached to a palace. It is intended for rest and shelter for persons walking in the garden, and also for the reception and protection of a number of

bas-reliefs and statues. It forms the principal object in looking across the garden from the windows of the palace, and should have the architectural character appropriate to its position and uses. It must be of only one story in height, and may be covered either by an inclined roof or by a terrace surrounded by balustrades. There must be in some part walls for the bas-reliefs. But, in general, the structure is not enclosed, and the roof is supported by arcades or colonnades. The width of these openings should not be much less than five nor much more than ten feet. Mansard roofs are not to be used. The greatest linear dimension must not exceed eighty feet. The building must comprise, within or around it, seats for conversation, steps, fountains, vases, &c.

REQUIRED: *A Plan*, on a scale of one-sixteenth of an inch to the foot, showing the arrangement of the garden in the neighborhood of the portico; *A principal Elevation*, and a *Section*, on a scale of one-eighth of an inch to the foot. This difference of scale will be found convenient in practice, as the total dimensions shown on the plan can be laid off on each side of symmetrical axes in elevation.

The whole to be drawn on two-thirds of a sheet of Whatman, the border lines enclosing the sketch being 17 and 19 inches long. To be handed in, drawn in pencil, shaded in pencil or India ink, and tinted, on Wednesday, December 24, at half-past three o'clock. Put your names and the date *on the back of the drawings*, with a minute of the time spent upon them, beginning with this morning's hour.

A PERISTYLE. *December* 29.

We suppose a public building, built on three sides of a hollow square, to be entered by a porch or portico, of six Corinthian columns, surmounted by a pediment and preceded by flights of steps, and situated at the bottom of the court-yard. Elsewhere the court-yard is surrounded by a colonnade, which is interrupted by the portico, and which is of much smaller dimensions. It may be of either order. Arches are not permitted. The hexastyle portico will have columns twenty-five feet high, including base and capital. The size of the others is left to the taste and judgment of the designer.

REQUIRED: *An Elevation* of the portico, showing both orders, on a scale of a quarter of an inch to the foot.

A Side Elevation, showing a section of the colonnade, to the same scale.

A Plan, on a scale of an eighth of an inch to the foot, showing the entrance doorway or doorways and indicating the vestibule within.

These to be drawn on a single sheet of Whatman's Imperial and cut up to a uniform size of 18 inches by 28. To be finished with the shadows cast in India ink, either in pencil or line, with or without color, on Monday,

January 12, at 3.30 P. M. Put on the back of drawing name, date, and number of hours' work.

A Flower Stand. *January* 2.

This little structure is for the sale of flowers in a public square or park. It must be constructed of iron, open on three sides at least, with projecting roof to give shade. It may be raised on a platform of stone, with balustrades; and is to cover, exclusive of the platform, about one hundred square feet.

Required: *A Plan*, on a scale of a quarter of an inch to a foot; an *Elevation*, double that scale; and details, showing the construction, on a scale of one inch to a foot. All on a single Imperial sheet.

A Grand Staircase. *January* 12.

This staircase is supposed to occupy the central hall or vestibule of some public building, such as a State House, Library, or Museum, in which the principal rooms are in the second story. It must be built of stone or marble. The hall or vestibule is to be covered by a vaulted or domed ceiling, and may be lighted either from above or by windows on one side, where the hall may be supposed to come to an external wall. The form of this hall, as well as that of the vault above and the disposition of the stairway itself, and the means of supporting them, is left to the judgment of each student. The staircase will extend only from the ground floor to the main floor, and the area of the hall will be about 2,000 or 3,000 square feet. The height of stories is not fixed.

Required: I. *A Plan* of the Hall taken at the level of the main story looking down upon the staircase, and showing three doorways, by which access is had to the principal apartments.

II. *Two Sections* taken vertically, at right angles to each other, showing the design of the staircase, of the vaulted or domed roof, and of the hall or vestibule in both stories. All on a uniform scale of $\frac{1}{12}$ in. = 1 ft.

The drawings will be on half sheets of Imperial paper, and will be inked in and colored, with the shadows cast. A brown-paper sketch will be made on Tuesday morning, January 13, and the drawings handed in on Thursday evening, January 22.

A Billiard Room. *February* 4.

This little building is situated on a bank, ten or fifteen feet above a stream navigable for row-boats and wherries, and surrounded elsewhere by gardens, of which it is a principal ornament. It comprises, besides the Billiard Room itself, the following parts:—

1. A Porch, open or enclosed.

2. A semi-circular Veranda, in the Ionic order, without arches.

3. A Belvidere, covering the whole or a part of the building, covered by a roof, but without walls, and communicating with a staircase. This staircase may be either external or internal.

4. A landing for boats, on a level with the water below, with proper steps and balustrades leading up to the garden and Billiard Room.

The Billiard Room itself is to be eighteen feet wide by twenty-four feet long in the clear, exclusive of niches, alcoves, recesses, and seats for spectators of the game. It must be lighted by windows in the side walls, the arrangement and composition of which constitute a chief point in the problem. But light from the roof, over the billiard table, may also be introduced if desired. The table is six feet by twelve.

The walls and cornice of the building are to be of light-colored stone or marble, as also the steps and balustrades. The ceilings may be of wood or plaster, and the roof and eaves of the Belvidere may be of wood.

REQUIRED: *A Plan*, showing the adjacent parts of the garden, steps, landing, &c., on a scale of an eighth of an inch to the foot.

A Principal Elevation, showing the steps down to the landing, on the same scale.

A Section and another Elevation, on a smaller scale.

A Plan of the roofs, looking down.

The whole to be drawn on a single sheet of Whatman's paper, fourteen inches by nineteen inches, finished as a sketch in pencil and color, with the shadows cast in India ink. To be handed in on Monday, February 16, at half-past three o'clock, P. M.

A CAFE. *February* 8.

This building, which is supposed to stand in a park or pleasure garden, must contain: —

1. The café itself, with proper kitchen, serving rooms, supper rooms, and a lodging for the proprietor.

2. A little theatre for singing and dancing, with the stage under cover, but the orchestra and audience out of doors in a garden.

3. Porticos, or covered walks, enclosing this garden,

The greatest dimensions of the plan must not exceed 100 feet.

REQUIRED: *Plan, Section, and Elevation*, finished in color or India ink on a uniform scale of sixteen feet to the inch.

A POMPEIAN HOUSE. *February* 21.

REQUIRED: To take the plan of some house at Pompeii, as given by Mazois, Zahn, Sir William Gell, Falkener, or any other accessible author-

ity, or in the plan of Pompeii, and to draw it out on a convenient scale, say one eighth of an inch to a foot. Also, to make a section on a larger scale, through the different *Cavædia*.

The whole to be finished in color, the ruined parts being restored, the roof added, and the decorations copied or adapted from photographs and prints.

The whole to be finished and handed in on Tuesday, March 10.

THE USE OF FOUR COLUMNS. *March* 5.

A wealthy amateur of the arts is in possession of the shafts of four columns of rich marble, which he wishes to make use of in the erection of a small building or monument. As these columns can serve equally well to form part of a great variety of structures, each student is left free to choose the subject of his composition. It may be a fountain, well, portico, tomb, or any other structure whatever.

These columns are to be taken as twelve feet long, exclusive of base and capital, which are to be supplied. Any substructure or base that the nature of the composition may require may be added.

REQUIRED: *A Plan and Elevation*, both on a scale of one fourth of an inch to the foot, finished in pencil, with the shadows cast, with or without color. To be handed in Tuesday morning, March 10, along with the Pompeian Houses.

A MONUMENTAL BRIDGE. *March* 13.

It is supposed that two neighboring nations, having settled by arbitration a question of boundary, agree to erect over a stream, which forms the frontier determined upon, a bridge, which shall at the same time serve to promote friendly intercourse and to preserve the memory of their compact, as an example to future generations. The stream at the point selected lies a hundred feet below the level of the proposed road, which passing along the slope of the mountain which forms one bank, until it reaches the narrowest part of the ravine, here crosses to the opposite side. The engineers report that good foundation for masonry may be had, if desired, in the bed of the stream. It is necessary to erect at each extremity of the bridge one or two small buildings to serve as custom-houses, with lodgings for the officer in charge, and a guard-room in which to quarter a dozen men on occasion, besides a room for the inspection and weighing of baggage and merchandise. There should also be a small lock-up for the detention of smugglers and other prisoners. Also a gate across the road. From one of these custom-houses to the other the length of the bridge is one hundred feet, and its width, within the parapets, thirty feet, comprising a carriage-way and two narrow foot-ways. In the centre of the bridge, over the middle of the

stream and marking the exact boundary, is to be a triumphal arch, or Arch of Peace, of such character and dimensions as may best suit the rest of the composition. The carriage-way may here be reduced, if desired, to ten feet. The custom-houses, bridge, and arch are all to be built of light-colored stone or of marble, and are all to form part of a single architectural composition.

REQUIRED: *A Plan, Elevation, and Section*, showing the Arch of Peace, all on a single Imperial sheet, drawn to a uniform scale of twelve feet to the inch. Sketches to be made by Wednesday, P. M., March 18, and finished drawings to be handed in on Monday, March 30, at half-past three o'clock, P. M.

Sketches to be on the scale of 24 inches to the foot. Give the number of hours' work, from this date.

A SCHOOL OF ARCHITECTURE. *April* 1.

We suppose that the vacant lot belonging to the Institute and adjoining the present building has been devoted to our own use, and that the Department is called upon to say what sort of a building is needed for its accommodation. To this end the class will furnish sketches, embracing the following points, with such further suggestions as their observation and experience may supply.

1. An Entrance Hall.
2. Proper staircases.
3. A Public Lecture Room to seat about 200 persons.
4. A Museum of Casts, accessible to the public, and convenient to the lecture room.
5. A Museum of Building Materials and Models.
6. Two small Lecture Rooms for 100 students each, one for history and design, one for construction.
7. One or more rooms for Library and Reading Room.
8. One or more rooms for Architectural Drawing, with accommodations for 100 students.
9. A room for Crayon Drawing, from casts and from the life, and a room for modelling in clay and plaster.
10. A Laboratory for Carpentry, Masonry, Painting, Metal-work, etc.
11. A Carpenter's Shop.
12. Four private rooms, two large and two small.
13. Proper provisions for W. C., Wash Rooms, etc.
14. A Lift or Dumb Waiter, and proper Ventilating Shafts.

The building to be built of brick and stone, with two stories each fifteen feet high, and a basement in which may be put some of the rooms. It is desired that the whole building shall cover about 6,000 square feet, and

that it shall not exceed 110 feet in any dimension. The Lecture Rooms should give six or eight square feet to each person, inclusive of aisles and platform. The sketches to be handed in on Tuesday afternoon, April 14, and to comprise two plans and two elevations, in pencil, on a scale of one-sixteenth of an inch to the foot, with the shadows cast in India ink.

A Railway Station. *April 4.*

A railroad, with double track, is supposed to pass under the main street of a country village. It is proposed to cross it by an arched bridge of a single span, and to build the station upon this bridge. It is to be of wood, stone, or brick, and iron, and to comprise, besides the ordinary waiting-rooms, baggage-rooms, and offices, convenient verandahs, and covered stairways leading down to the platforms, on a level with the tracks.

Required: *A Plan, Section, and two Elevations*, on a scale of eight feet to an inch, and a third elevation and a plan of the roofs on a smaller scale, all on one sheet of Imperial.

Also: A portion of the building drawn out on a scale of half an inch to the foot, with details on a scale of one inch to the foot.

Students who are candidates for a degree will present these drawings as part of their Graduating Thesis, and will submit along with them calculations of the strength and stability of the principal parts of the structure.

The work must be done by the 15th of May.

APPENDIX.

CORPORATION FOR 1875–76.

President,

JOHN D. RUNKLE.

Secretary,	**Treasurer,**
SAMUEL KNEELAND.	JOHN CUMMINGS.

Committee on the School of Industrial Science,

JOHN AMORY LOWELL, *Chairman,*	EDWARD S. PHILBRICK,
EDWARD ATKINSON,	JOHN D. PHILBRICK,
THOMAS T. BOUVÉ,	WILLIAM B. ROGERS,
J. ELIOT CABOT,	J. BAXTER UPHAM,
GEORGE B. EMERSON,	

Treasurer, *ex-officio.*

Committee on Finance,

HENRY P. KIDDER, *Chairman,*	JOHN M. FORBES,
J. INGERSOLL BOWDITCH,	JAMES L. LITTLE,
WILLIAM ENDICOTT, Jr.,	SAMUEL D. WARREN,

Treasurer, *ex-officio.*

Committee on the Museum,

ERASTUS B. BIGELOW, *Chairman,*	E. R. MUDGE,
CHARLES H. DALTON,	M. D. ROSS,
JOSEPH S. FAY,	STEPHEN P. RUGGLES,
AUGUSTUS LOWELL,	NATHANIEL THAYER.
HORACE McMURTRIE,	

Committee on the Society of Arts,

MARSHALL P. WILDER, *Chairman,*	J. C. HOADLEY,
PHILLIPS BROOKS,	FRED. W. LINCOLN,
J. WILEY EDMANDS,	SAMUEL K. LOTHROP,
CHARLES L. FLINT,	ALEXANDER H. RICE,
JAMES B. FRANCIS,	HENRY B. ROGERS.

On the Part of the Commonwealth,

His Excellency, Governor ALEXANDER H. RICE.

Hon. HORACE GRAY, *Chief Justice of the Supreme Court.*

Hon. JOSEPH WHITE, *Secretary of the Board of Education.*

COMMITTEES

TO VISIT AND INSPECT THE SEVERAL DEPARTMENTS

OF THE SCHOOL.

Civil Engineering.

EDWARD S. PHILBRICK.
C. H. DALTON.
C. L. FLINT.
J. B. FRANCIS.
JOHN D. RUNKLE.

Mechanical Engineering.

E. B. BIGELOW.
W. B. ROGERS.
C. H. DALTON.
J. C. HOADLEY.
F. W. LINCOLN.

Mining Engineering.

T. T. BOUVÉ.
JOS. S. FAY.
H. P. KIDDER.
E. S. PHILBRICK.
M. D. ROSS.

Architecture.

J. B. UPHAM.
PHILLIPS BROOKS.
J. ELIOT CABOT.
G. B. EMERSON.
JOHN M. FORBES.

General and Analytical Chemistry.

W. B. ROGERS.
T. T. BOUVÉ.
J. WILEY EDMANDS.
S. D. WARREN.
M. P. WILDER.

Industrial Chemistry and Metallurgy.

T. T. BOUVÉ.
EDWARD ATKINSON.
J. L. LITTLE.
H. B. ROGERS.
W. B. ROGERS.

Natural History.

JOHN CUMMINGS.
G. B. EMERSON.
H. B. ROGERS.
W. B. ROGERS.
M. D. ROSS.

Physics.

W. B. ROGERS.
J. INGERSOLL BOWDITCH.
J. D. PHILBRICK.
STEPHEN P. RUGGLES.
J. B. UPHAM.

English and History.

G. B. EMERSON.
WM. ENDICOTT, JR.
AUGUSTUS LOWELL.
E. R. MUDGE.
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Philosophy and Political Economy.

J. ELIOT CABOT.
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WM. ENDICOTT, JR.
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AUGUSTUS LOWELL.

Modern Languages.

AUGUSTUS LOWELL.
EDWARD ATKINSON.
J. ELIOT CABOT.
C. L. FLINT.
J. D. PHILBRICK.

Mathematics.

J. D. RUNKLE.
J. B. FRANCIS.
J. A. LOWELL.
H. McMURTRIE.
A. H. RICE.

Mechanics.

J. D. RUNKLE.
J. INGERSOLL BOWDITCH.
J. C. HOADLEY.
E. S. PHILBRICK.
STEPHEN P. RUGGLES.

Industrial Design.

J. A. LOWELL.
EDWARD ATKINSON.
J. L. LITTLE.
E. R. MUDGE.
A. H. RICE.

Free Hand and Mech. Drawing.

J. D. PHILBRICK.
PHILLIPS BROOKS.
C. H. DALTON.
H. P. KIDDER.
J. B. UPHAM.

Descrip. Geometry and Stereotomy.

E. S. PHILBRICK.
J. B. FRANCIS.
J. C. HOADLEY.
H. McMURTRIE.
J. D. RUNKLE.

Military Science and Tactics.

J. B. UPHAM.
C. H. DALTON.
E. R. MUDGE.
H. McMURTRIE.
A. H. RICE.

Museum and Collections.

STEPHEN P. RUGGLES.
EDWARD ATKINSON.
AUGUSTUS LOWELL.
M. D. ROSS.
J. D. RUNKLE.

OFFICERS OF INSTRUCTION.

President.

JOHN D. RUNKLE, PH.D., LL.D.

JOHN D. RUNKLE, PH.D., LL.D.
Walker Professor of Higher Mathematics.

JOHN B. HENCK, A.M.,
Hayward Professor of Civil and Topographical Engineering.

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WILLIAM P. ATKINSON, A.M.,
Professor of English and History.

GEORGE A. OSBORNE, S.B.,
Professor of Mathematics.

EDWARD C. PICKERING, S.B.,
Thayer Professor of Physics, and Director of the Rogers Laboratory.

SAMUEL KNEELAND, A.M., M.D.,
Professor of Zoology and Physiology.

JOHN M. ORDWAY, A.M.,*
Professor of Metallurgy and Industrial Chemistry.

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ROBERT H. RICHARDS, S.B.,
Professor of Mining Engineering, and Director of the Mining and Metallurgical Laboratories.

THOMAS STERRY HUNT, LL.D.,
Professor of Geology.

GEORGE H. HOWISON, A.M.,
Professor of Logic and the Philosophy of Science.

WM. RIPLEY NICHOLS, S.B.,
Professor of General Chemistry.

CHARLES P. OTIS, PH.D.
Professor of Modern Languages.

CHARLES H. WING, S.B.,
Professor of Analytical Chemistry.

HENRY L. WHITING, U. S. Coast Survey,
Professor of Topography.

HENRY MITCHELL, A.M., U. S. Coast Survey,
Professor of Physical Hydrography.

ALPHEUS HYATT, S.B., Custodian of the Boston Society of Natural History,
Professor of Palæontology.

* The instruction in Botany is at present given by Prof. Ordway.

WILLIAM H. NILES, PH.B., A.M.,
Professor of Physical Geology and Geography.

LIEUT. E. L. ZALINSKI, U. S. A.,
Professor of Military Science and Tactics.

CHANNING WHITAKER, S.B.,
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CHARLES R. CROSS, S.B.,
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GAETANO LANZA, S.B., C.E.,
Professor of Theoretical and Applied Mechanics.

EUGENE LETANG,
Assistant in Architecture.

WILLIAM E. HOYT, S.B,
Instructor in Civil Engineering and Stereotomy.

JULES LUQUIENS, PH.D.,
Instructor in Modern Languages.

CHARLES KASTNER,
Lowell Instructor in Practical Design.

WEBSTER WELLS, S.B.,
Instructor in Mathematics and Descriptive Geometry.

THOMAS E. POPE, A.M.,
Instructor in Quantitative Analysis.

FRANK B. MORSE, S.B.,
Instructor in Free-hand Drawing.

HENRY N. MUDGE,
Instructor in Mechanical and Free-hand Drawing.

WILLIAM FOSTER,
Assistant in the Mining and Metallurgical Laboratories.

FRANCIS T. SARGENT, S.B.,
Assistant in Mechanical Engineering.

J. AUSTIN KNAPP, S.B.,
Assistant in Mechanical Engineering.

LEWIS M. NORTON,
Assistant in Quantitative Analysis.

CHARLES C. R. FISH,
Assistant in General Chemistry and Qualitative Analysis.

WILLIAM E. NICKERSON,
Assistant in General Chemistry and Qualitative Analysis.

WILLIAM O. CROSBY,
Assistant in Palæontology.

CONDITIONS OF ADMISSION.

To be admitted as a regular student of the first year's class, applicants must have attained the age of sixteen years, and must pass a satisfactory examination in arithmetic (including the metric system of weights and measures), algebra through equations of the second degree, plane and solid geometry, including spherical geometry, French grammar through regular and irregular verbs, and the first two books of Voltaire's "Charles XII" (*i.e.*, about sixty pages) or the equivalent of the same, English grammar, including, especially, the ability to detect the parts of speech, to use correctly the conjugation of verbs regular and irregular, to classify terms as Singular, General, and Universal, and to analyze phrases and sentences, English composition, rhetoric (so much as is included in the first part of Bain's Rhetoric, or its equivalent), history of the United States, and geography. In general, the training given at the best High Schools, Academies, and Classical Schools, will be a suitable preparation for this School.

Graduates of Colleges will, in general, be presumed to have the requisite attainments for entering the third year as regular students, and may do so on satisfying the department which they purpose to enter that they are prepared to pursue their studies to advantage. Such students, if deficient in any of the scientific studies of the first two years, will have opportunities for making them up without extra charge, and will be required to pass an examination in them before entering upon the studies of the fourth year. Should they be already proficient in any of the general studies of the third and fourth years, they will be excused, if they wish, from attendance on the exercises in these subjects.

REGULAR COURSES.

ALL COURSES. — FIRST YEAR.

			No. of Exercises	Hrs. per week
1	Algebra finished	1st half	45	5
	Plane and Solid Geometry reviewed	2d half	15	3
	Plane and Spherical Trigonometry	2d half	30	3
2	General Chemistry	1st half	60	6
	General Chemistry	2d half	30	2
	Qualitative Analysis	2d half	30	4
3	Structure of the Sentence	1st half	30	2
	Rudiments of Logic	2d half	30	2
4	French		90	3
5	Mechanical Drawing and Elements of Descriptive Geometry and Perspective		90	6
6	Free Hand Drawing		90	3
7	Physiology and Hygiene	2d half	30	2
8	Military Tactics		90	3

I. CIVIL ENGINEERING.

SECOND YEAR.

			No. of Exercises.	Hrs. per week.
1	Analytic Geometry	1st half	45	3
	Calculus	2d half	45	3
2	Descriptive Geometry	1st half	30	2
	Mechanical Drawing	1st half	30	4
	Surveying		60	2
	Topographical and Plan Drawing	2d half	30	4
3	Physics (Lectures)		90	3
4	French finished, German begun		90	3
5	Rhetoric and English Literature, or Descriptive Astronomy	1st half	30	2
6	English Literature, or Physical Geography	2d half	30	2
7	Military Science		24	1

THIRD YEAR.

1	Survey and Location of Roads	1st half	45	6
	Construction of Roads	2d half	20	6
	Water supply, Drainage, etc.	2d half	25	6
	Field Practice		30	3
	Stereotomy	1st half	30	4
	Bridge and Roof Construction	2d half	30	4
2	Calculus	½ year	25	3
	Applied Mechanics	½ year	65	3
3	German		90	3
4	Physical Laboratory		60	2
5	Outlines of Zoology, or History	1st half	30	2
6	General Geology, or Political Economy	2d half	30	2

FOURTH YEAR.

1	Stability of Structures	1st half	20	6
	Strength of Materials	1st half	25	6
	Structures of Stone	2d half	15	6
	Structures of Wood	2d half	10	6
	Structures of Metal	2d half	20	6
	Topography (Field Practice)	2d half	10	
	Physical Hydrography	2d half	10	
	Structure Drawing	2d half	45	6
	Building Materials	2d half	10	3
2	Water power and Water wheels	2d half	25	4
3	Metallurgy of Iron	1st half	30	2
4	Applied Physics	1st half	30	2
5	German	1st half	45	3
6	Philosophy of Science	1st half	45	3

In addition to the prescribed studies, optional studies, selected from other courses, may be taken.

II. MECHANICAL ENGINEERING.

SECOND YEAR.

			No. of Exercises	Hrs. per week.
1	Analytic Geometry	1st half	45	3
	Calculus	2d half	45	3
2	Descriptive Geometry	1st half	30	2
	Mechanical Drawing	1st half	30	4
	Principles of Mechanism	1st half	30	2
	Principles of Mechanism	2d half	60	4
	Machine Drawing	2d half	30	4
3	Physics (Lectures)		90	3
4	French finished, German begun		90	3
5	Rhetoric and English Literature, or Descriptive Astronomy	1st half	30	2
6	English Literature, or Physical Geography	2d half	30	2
7	Military Science		24	1

THIRD YEAR.

1	Machinery and Millwork	$\frac{3}{4}$ year	80	6
	Strength of Materials	$\frac{1}{4}$ year	40	6
	Mechanical Laboratory		30	2
	Machine Drawing		60	4
2	Calculus	$\frac{1}{2}$ year	25	3
	Applied Mechanics	$\frac{1}{2}$ year	65	3
3	German		90	3
4	Physical Laboratory		60	2
5	Outlines of Zoology, or History	1st half	30	2
6	General Geology, or Political Economy	2d half	30	2

FOURTH YEAR.

1	Principles of Thermodynamics	1st half	90	6
	Mechanism of the Steam Engine	2d half	50	8
	Water power and Water wheels	2d half	70	8
	Machine Drawing		90	6
	Mechanical Laboratory		105	7
	Building Materials	2d half	10	3
2	Metallurgy of Iron	1st half	30	3
3	German	1st half	45	3
4	Philosophy of Science	1st half	45	3

In addition to the prescribed studies, optional studies, selected from other courses, may be taken.

III. MINING ENGINEERING.

SECOND YEAR.

			No. of Exercises.	Hrs. per week.
1	Analytic Geometry	1st half	45	3
	Calculus	2d half	45	3
2	Qualitative Analysis	1st half	45	6
	Drawing	1st half	30	2
	Mineralogy	2d half	45	6
	Botany	2d half	30	2
3	Physics (Lectures)		90	3
4	French finished, German begun		90	3
5	Rhetoric and English Literature, or Descriptive Astronomy	1st half	30	2
6	English Literature, or Physical Geography	2d half	30	2
7	Military Science		24	1

THIRD YEAR.

1	Chemical Laboratory		150	10
	General Quantitative Analysis (Lectures)	1st half	30	2
	Mining Engineering		90	3
	Assaying	2d half	15	3
	Structural Palæontology	2d half	15	2
2	Calculus	½ year	25	3
	Applied Mechanics	½ year	65	3
3	German		90	3
4	Physical Laboratory		60	2
5	Outlines of Zoology, or History	1st half	30	2
6	General Geology, or Political Economy	2d half	30	2

FOURTH YEAR.

1	Ore dressing	½ year	15	3
	Metallurgy	½ year	45	3
	Drawing	1st half	30	2
	Mining and Metallurgical Laboratory	2d half	75	10
	Chemical Laboratory		150	10
2	American Geology	1st half	40	3
	Coal and Ore Deposits	2d half	15	3
	Building Materials	2d half	10	3
	Chemical Geology	2d half	15	3
3	German	1st half	45	3
4	Philosophy of Science	1st half	45	3

In addition to the prescribed studies, optional studies, selected from other courses, may be taken.

IV. ARCHITECTURE.

SECOND YEAR.

			No. of Exercises	Hrs. per week.
1	Analytic Geometry	1st half	45	3
	Calculus	2d half	45	3
2	Descriptive Geometry	1st half	30	2
	Mechanical Drawing	1st half	30	4
	Shades, and Shadows	2d half	30	2
	The Orders	1st quar.	16	2
	Greek and Roman Arch. History	2d quar.	14	2
	Architectural History and Design	2d half	30	2
3	Physics (Lectures)		90	3
4	French finished, German begun		90	3
5	Rhetoric and English Literature, or Descriptive Astronomy	1st half	30	2
6	English Literature, or Physical Geography	2d half	30	2
7	Military Science		24	1

THIRD YEAR.

1	Theory of Architecture	1st half	15	1
	Architectural History and Design	2d half	30	2
	Stereotomy	1st half	30	4
	Mechanical Drawing	1st half	30	4
	Architectural Drawing		150	10
	Specifications and Working Drawings		30	1
2	Calculus	½ year	25	3
	Applied Mechanics	½ year	65	3
3	German		90	3
4	Physical Laboratory		60	2
5	Outlines of Zoology, or History	1st half	30	2
6	General Geology, or Political Economy	2d half	30	2

FOURTH YEAR.

1	Architectural History and Design		30	1
	Architectural Ornament and Detail		30	1
	Specifications and Working Drawings		30	1
	Architectural Drawing		150	10
2	Stability of Structures	1st half	20	6
	Strength of Materials	1st half	25	6
	Structures of Stone	2d half	15	6
	Structures of Wood	2d half	10	6
	Structures of Metal	2d half	20	6
	Building Materials	2d half	10	3
3	Applied Physics	1st half	30	2
4	German	1st half	45	3
5	Philosophy of Science	1st half	45	3

In addition to the prescribed studies, optional studies, selected from other courses, may be taken.

V. CHEMISTRY.

SECOND YEAR.

			No. of Exercises.	Hrs. per week.
1	Qualitative Analysis	1st half	45	6
	Mineralogy	2d half	45	6
2	Chemical Philosophy	1st half	45	3
	Botany	2d half	30	2
3	Physics (Lectures)		90	3
4	French finished, German begun		90	3
5	Rhetoric and English Literature, or Descriptive Astronomy	1st half	30	2
6	English Literature, or Physical Geography	2d half	30	2
7	Military Science and Tactics		24	1

THIRD YEAR.

	Chemical Laboratory		150	12
	General Quantitative Analysis (Lectures)	1st half	30	2
	Quant. Anal., Special Methods (Lectures)	2d half	30	2
	Industrial Chemistry	2d half	45	3
2	Chemical Physiology	1st half	30	2
	Structural Palæontology	2d half	15	2
3	German		90	3
4	Physical Laboratory		60	2
5	Outlines of Zoology, or History	1st half	30	2
6	General Geology, or Political Economy	2d half	30	2

FOURTH YEAR.

1	Chemical Laboratory		150	15
	Organic Chemistry (Lectures)		60	2
	Metallurgy	½ year	45	3
	Drawing	1st half	30	2
2	American Geology	1st half	40	3
	Chemical Geology	2d half	15	3
	Coal and Ore Deposits	2d half	15	3
	Building Materials	2d half	10	3
	Assaying	2d half	10	
3	Applied Physics	1st half	30	2
4	German	1st half	45	3
5	Philosophy of Science	1st half	45	3

In addition to the prescribed studies, optional studies, selected from other courses, may be taken.

VI. METALLURGY.

SECOND YEAR.

			No. of Exercises.	Hrs. per week.
1	Qualitative Analysis	1st half	45	6
	Mineralogy	2d half	45	6
2	Chemical Philosophy	1st half	45	3
	Botany	2d half	30	2
3	Physics (Lectures)		90	3
4	French finished, German begun		90	3
5	Rhetoric and English Literature, or Descriptive Astronomy	1st half	30	2
6	English Literature, or Physical Geography	2d half	30	2
7	Military Science		24	1

THIRD YEAR.

	Chemical Laboratory		150	12
	General Quantitative Analysis (Lectures)	1st half	30	2
	Quant. Anal., Special Methods (Lectures)	2d half	30	2
1	Industrial Chemistry	2d half	45	3
2	Chemical Physiology	1st half	30	2
	Structural Palæontology	2d half	15	2
	Assaying	2d half	15	3
3	German		90	3
4	Physical Laboratory		60	2
1	Outlines of Zoology, or History	1st half	30	2
5	General Geology, or Political Economy	2d half	30	2

FOURTH YEAR.

6	Ore-dressing	½ year	15	3
	Metallurgy	½ year	45	3
	Drawing	1st half	30	2
	Mining and Metallurgical Laboratory	2d half	75	10
	Chemical Laboratory		150	10
2	American Geology	1st half	40	3
	Coal and Ore Deposits	2d half	15	3
	Building Materials	2d half	10	3
	Chemical Geology	2d half	15	3
3	German	1st half	45	3
4	Philosophy of Science	1st half	45	3

In addition to the prescribed studies, optional studies, selected from other courses, may be taken.

VIII. PHYSICS.

SECOND YEAR.

			No. of Exercises.	Hrs. per week.
1	Analytic Geometry	1st half	45	3
	Calculus	2d half	45	3
2	Qualitative Analysis	1st half	45	6
	Quantitative Analysis	2d half	45	6
	Chemical Philosophy	1st half	45	3
	Botany	2d half	30	2
3	Physics (Lectures)		90	3
4	French finished, German begun		90	3
5	Rhetoric and English Literature, or Descriptive Astronomy	1st half	30	2
6	English Literature, or Physical Geography	2d half	30	2
7	Military Science		24	1

THIRD YEAR.

1	Physical Laboratory		120	4
	Physics (additional Lectures)		60	2
2	Calculus	½ year	25	3
	Applied Mechanics	½ year	65	3
	Strength of Materials	2d half	30	4
3	General Quantitative Analysis (Lectures)	1st half	30	2
	Chemical Physiology	1st half	30	2
	Chemical Laboratory	1st half	45	6
4	German		90	3
5	Outlines of Zoology, or History	1st half	30	2
6	General Geology, or Political Economy	2d half	30	2

FOURTH YEAR.

1	Physical Research		150	10
	Advanced Physics		30	2
	Photography	1st half	15	4
	Lantern Projections	1st half	15	4
2	Chemical Laboratory	2d half	75	10
3	Practical Astronomy	1st half	30	3
	Mechanical Engineering	1st half	15	3
4	Principles of Thermodynamics	1st half	60	4
5	American Geology	1st half	40	3
	Chemical Geology	2d half	15	3
	Coal and Ore Deposits	2d half	15	3
	Building Materials	2d half	10	3
*6	German		90	3
7	Philosophy of Science	1st half	45	3
	Political and Industrial Geography	2d half	30	

In addition to the prescribed studies, optional studies selected from other courses, may be taken.

VII. NATURAL HISTORY.

SECOND YEAR.

			No. of Exercises.	Hrs. per week.
1	Chemical Philosophy	1st half	45	3
	Botany	2d half	30	2
2	Qualitative Analysis	1st half	45	6
	Mineralogy	2d half	45	6
3	Physics (Lectures)		90	3
4	French finished, German begun		90	3
5	Rhetoric and English Literature, or Descriptive Astronomy	1st half	30	2
6	English Literature, or Physical Geography	2d half	30	2
7	Military Science		24	1

THIRD YEAR.

1	General Quantitative Analysis (Lectures)	1st half	30	2
	Comparative Zoology	2d half	45	3
	Chemical Laboratory		150	10
2	Chemical Physiology	1st half	30	2
	Structural Palæontology	2d half	15	2
3	German		90	3
4	Physical Laboratory		60	2
5	Outlines of Zoology, or History	1st half	30	2
6	General Geology, or Political Economy	2d half	30	2

FOURTH YEAR.

1	Special Zoology, Special Geology, Special Botany, or Special Stratigraphical Palæontology	Laboratory	180	12
2	American Geology	1st half	40	3
	Coal and Ore Deposits	2d half	15	3
	Building Materials	2d half	10	3
	Chemical Geology	2d half	15	3
3	Applied Physics	1st half	30	2
4	German		90	3
5	Philosophy of Science	1st half	45	3
	Political and Industrial Geography	2d half	30	2

In addition to the prescribed studies, optional studies, elected from other courses, may be taken.

IX. SCIENCE AND LITERATURE.

SECOND YEAR.

			No. of Exercises.	Hrs. per week.
1	Rhetoric and English Literature		90	3
	Elements of Philosophy	2d half	45	3
2	Chemical Philosophy	1st half	45	3
	Botany	2d half	30	2
3	Physics (Lectures)		90	3
4	French finished, German begun		90	3
5	Descriptive Astronomy	1st half	30	2
	Physical Geography	2d half	30	2
6	Military Science		24	1

THIRD YEAR.

1	History		90	3
2	Advanced French		90	3
3	German		90	3
4	Physical Laboratory		60	2
5	Outlines of Zoology	1st half	30	2
	General Geology	2d half	30	2
6	History of Commerce and Industry	1st half	30	2
	Political Economy	2d half	30	2

FOURTH YEAR.

1	Earlier English Literature	1st half	45	3
	Science of Language	2d half	45	3
2	Business Law	1st half	30	2
	Political and Industrial Geography	2d half	30	2
3	American Geology	1st half	40	3
	Chemical Geology	2d half	15	3
	Coal and Ore Deposits	2d half	15	3
	Building Materials	2d half	10	3
4	German		90	3
5	Constitutional History		60	2
6	Philosophy of Science	1st half	45	3
	Applied Physics	1st half	30	2

In addition to the prescribed studies, optional studies selected from other courses, may be taken.

X. PHILOSOPHY.

SECOND YEAR.

			No. of Exercises.	Hrs. per week.
1	Applied Logic	1st half	45	3
	Elements of Philosophy, viz.,	2d half	45	3
	(a) Its Definition and General Problems (5 lectures)			
	(b) The Solutions proposed by the several Schools (10 lectures).			
	(c) Résumé of Terminology (5 lectures)			
	(d) Outlines of Psychology (25 lectures)			
2	French finished, German begun		90	3
3	Analytic Geometry	1st half	45	3
	Calculus	2d half	45	3
4	Physics (Lectures)		90	3
5	Chemical Philosophy	1st half	45	3
6	English Literature	2d half	45	3
7	Military Science		24	1

THIRD YEAR.

1	Philosophy: Critical History of Modern Systems		150	5
	(a) Descartes, Spinoza, Locke. (1st half, 75 lectures.)			
	(b) Leibnitz, Berkeley, Hume. (2d half, 60 lectures.)			
	(c) Reid, the Transition to Kant. (2d half. 15 lectures.)			
2	Advanced French		90	3
3	German		90	3
4	History	1st half	30	2
	Political Economy	2d half	30	2
5	Physical Laboratory	1st half	30	2
	General Geology	2d half	30	2

FOURTH YEAR.

1	Philosophy: Critical History of Modern Systems		150	5
	(a) Kant and Fichte. (1st half. 75 lectures.)			
	(b) Schelling and Hegel. (2d half. 75 lectures.)			
2	Philosophy of Science, viz.,	1st half	45	3
	(a) Theory of Induction—its precise nature as a Mental Process, its Conditions of Application, and its Five Auxiliary Methods (20 lectures).			
	(b) Classification of the Natural Sciences, with discussion of their Logical Connexion, and of the Logical System of each (10 lectures).			
	(c) Same treatment of the Mathematical Sciences (5 lectures)			
	(d) Logical Theory of the Calculus (10 lectures)			
	Science of Language	2d half	45	3
3	German		90	3
4	Earlier English Literature	1st half	45	3

In addition to the prescribed studies, optional studies selected from other courses, may be taken.

ARCHITECTURAL DEPARTMENT.—BOOKS.

Shelf.	*No.*	
A.	1.	Barbazat's Iron-work. 4to. 1867.
	2.	Ferme Ornée, Rural Improvements. 4to. 1795.
	3.	Rural Architecture.
	4.	Highland Cottages. Lang. 1848.
	5.	Domestic Economy (Heating and Cooking). C. Sylvester. 4to. 1819.
	6.	Rural Architect. J. Gandy. 4to. 1806.
	7.	Iron-work. Ducel Fils. 4to. 1867.
	8.	Crunden's Designs. 1785.
	9.	Downing's Landscape Gardening. 1841.
	10.	Béton Coignet. L. F. Beckwith. 8vo. 1868.
	11.	Carpenter's Ancient Carpentry. 1736.
	12.	Haupt on Bridge Construction. 1868.
B.	1, 6.	Fergusson's Handbook. 2 Vols. 3 copies. 1855.
	7, 10.	" History. 3 Vols. 1868.
C.	1–3.	Stuart's Dictionary of Architecture. 3 Vols.
	4.	Rickman's Gothic Architecture. 1862.
	5, 6.	Parker's Glossary. 2 Vols. 1841.
D.	1–6.	Murray's English Cathedrals. 6 Vols.
E.	1–5.	Gwilt's Encyclopedia of Architecture.
	6–7.	Billington's Architectural Director. 2 Vols. 1848.
	8.	Chambers's Civil Architecture. 4to.
F.	1.	Grüner's Fresco Decoration in Italy. Text.
	2, 3.	Proceedings of the American Institute of Architects. 2 Vols. 18 –1875.
	4.	Archæological Proceedings. Winchester. 1865.
	5.	Essex Archæological Society. 1848.
	6–20.	Papers of Architectural Institute of Scotland. 1850–1858.
G.	1.	Architectural Drawing Book. R. S. Burn. 1857.
	2.	Architectural Design. R. S. Burn. 1853.
	3.	Woodward's Rural Art. 1868.
	4–29.	Weale's Series.
		6. Mechanics. Tomlinson.
		16. Orders of Architecture. Leeds.
		17. Styles of Architecture. Bury.
		18. Principles of Design. Garbett.
		19. Art of Building. Dobson.
		23. Brick Making. Dobson.

Shelf.	No.	
G.	4 29.	Weale's Series (*continued*).
	25.	Masonry and Stone Cutting. Dobson.
	29. 30.	Drainage and Sewage. Dempsey.
	35.	Quarrying Stone. Burgoyne.
	36.	Dictionary of Terms.
	42.	Cottage Building. Allen.
	44.	Foundations and Concrete. Dobson.
	45.	Limes, Mortars, etc. Burnell.
	57.	Warming and Ventilation. Tomlinson.
	111.	Arches and Piers. Bland.
	116.	Acoustics. T. R. Smith.
	123.	Carpentry and Joinery. 2 Vols.
	124.	Roofs. 2 Vols.
	127.	Architectural Modelling. Richardson.
	128.	Vitruvius. Gwilt.
	130.	Grecian Architecture. Earl of Aberdeen.
	132.	Dwelling Houses. Brooks.
H.	1.	Ruskin. Stones of Venice. 3 Vols.
	2.	" Seven Lamps of Architecture.
	3.	" Two Paths.
	4.	" Political Economy of Art.
	5–9.	" Modern Painters.
I.		Documens Inedits sur l'histoire de France.
	1.	Iconographie Chrétienne.
	2.	N. D. de Noyon. Text. Vitet.
	3.	Chateau de Gaillon. Text.
	4.	Statistique Monumentale de Paris. Text.
	5–6.	Architecture Monastique. Lenoir. 2 Vols.
	7–11.	Dictionnaire du Mobilier Français. Viollet le Duc.
J.	1–10.	Dictionnaire Raisonné de l'Architecture Française. 10 Vols.
K, L, M, N.		Revue Generale de l'Architecture. 33 Vols.
O.	1.	Entretiens sur l'Architecture. Viollet le Duc. 1863.
	2.	The same. Translated by H. Van Brunt. 1875.
	3–5.	Traité de la Chaleur. 3 Vols. Peclet. 1845.
	6.	Edifices de Rome Moderne. Le Tarouilly (Text). 1860.
	7.	Nouvelles Inventions pour bien Bastir. Philibert de l'Orme. 1561.
P, Q, R, S.	23.	The Builder. 1843–1849, 1861, 1862, 1869, 1870.
T.		Papers of the Royal Institute of British Architects. 17 Vols.

Shelf.	*No.*	
U.	1–5.	Britton's Antiquities. 5 Vols. 1807.
	6.	Westminster Abbey. Neale. 1856.
	7.	Godwin's London. 1839.
	8.	Knight's Cyclopædia of London. 1851.
V.	1–4.	Study Book of Mediæval Art. 4 Vols. T. H. King. 1868.
W.	1.	Grammar of Ornament. (Small ed.) Owen Jones. 1856.
	2, 3.	Brandon's Gothic Analysis. 2 Vols. 1858.
	4.	Pugin's Gothic Ornament. 1854.
	5–8.	The Workshop. 4 Vols.
X.	1–4.	The Architect. Vols. V, and VI, 1871; VII, 1872; X, 1873.
Y.	1, 2.	Architecture Civile et Domestique. Verdier and Cattois. 1864.
	3.	Architecture Polychrome. Hittorff. (Text.) 1851.
	4.	Monuments du Musée National à Naples. 1867.
Z.	1–5.	Moniteur des Architectes. 5 Vols. 1866–1870.
AA.	1–7.	Gazette des Architectes. 1863–71.
BB.	1, 2.	Traité d'Architecture. L. Reynaud. Text. 1863.
	3, 4.	Perspective; Text and Plates. Adhémar.
	5.	Perspective Linéaire. Thibault.
	6.	Traité d'Architecture. Simonin and Thierry.
CC.	1.	Annales de la Soc. Centrale des Architectes. 1875.
DD.	1.	Le Chateau d'Anet. R. Pfnor. 1869.
	2.	Fragments. Bourgerel. 1862.
EE.	1.	Architecture Funéraire. C. Daly.
FF.	1.	Architectural Monuments of Egypt.
	2.	Compositions Antiques. Boucher.
	3.	Miscellaneous Elevations and Sections.
GG.	1–3.	Expédition de Morée. A. Blouet. 3 Vols. 1838.
HH.	1.	Grammar of Ornament. (Large ed.) O. Jones. 1856.
	2.	Grüner's Fresco Decorations. (Plates.) 1854.
II.	1–3.	L'Asie Mineure. Texier. 3 Vols. 1839.
JJ.	1–9.	Croquis d'Architecture. Intime Club. 9 Vols. 1867–1876.
KK.		
LL.	1.	La Cathédrale de Chartres. 1867.
	2.	Hotel de Ville de Paris. Calliat. 1851.
	3.	Chateau de Gaillon. (Plates.)
	4.	Notre-Dame de Noyon. (Plates.) 1845.
	5.	Miscellanea. Albertolli. 1796.
MM.	1–4.	Building Examples. 4 Vols. Henry Laxton. 1867.
NN.	1, 2.	Architectonische Studien. Stuttgart.

Shelf.	No.	
OO.	1–6.	Edifices de Rome Moderne. (Plates.) Le Tarouilly. 3 Vols. in 6.
PP.	1–2.	Traité d'Architecture. L. Reynaud. (Plates.) 2 Vols.
QQ.	1.	Chambers' Civil Architecture. 1768.
	2–5.	Sharpe's Parallels. 4 Vols.
RR.	1.	Maisons de Plaisance de Rome. Percier and Fontaine. 1809.
	2.	Maisons, Edifices et Monuments Publics de Paris. Krafft and Thiollet. 1849.
	3.	Foro Trajano. Albertolli. 1835.
SS.	1–4.	Ruines de Pompei. 4 Vols. Mazois. 1824.
TT.	1.	Architecture Polychrome. (Temple of Empedocles.) (Plates.) Hittorff.
	2.	Expedition to Sicily. (Plates.) Hittorff.
UU.	1–2.	Statistique Monumentale de Paris. 2 Vols. Albert Lenoir. 1867.
VV.	1.	Piranesi. 1750.
	2.	Récueil d'Architecture. F. L. Scheult. 1795?
	3.	Gally Knight's Italy. Second Series. 1843.
WW.	1.	New Law courts, Plans and Sections. Scott. 1868.
	2.	New Courts of Justice. Garling. 1867.
	3.	New Law courts, Plans and Sections. Street. 1868.
	4.	Deutsch-mittelalterlichen Baukunst. (Plates.) Kallenbach. 1847.
	5.	Die Badische Eisenbahn. (Plates.)
XX.	1.	Durand's Parallèle.
YY, ZZ, AB–AF.	32.	Illustrated London News. 32 Vols. 1851 to 1872, inclusive. Missing, 1851, January–June 1852, 1855, 1859, 1860, 1863, July–Dec. 1868, July–Dec. 1870, 1871.
AG.	1–4.	The Graphic. 4 Vols. 1871, 1872.
AH.	1, 2.	Annales de la Construction. 2 Vols. Text. 1855–1859.
	3, 4.	" " " " Plates.
	5, 6.	Architectural Notes. Plates and text. (Lithographed.)
AI.	1, 2.	Renaissance Monumentale en France. 2 Vols. Berty, 1864.
	3.	Sei Fabbriche in Firenze. Callesi. 1851.
	4.	Normand's Parallèle.
AJ.	1.	Unedited Antiquities of Attica. 1832.
	2–5.	Antiquities of Athens. 4 Vols. Stuart and Revett. 1812.
	6, 7.	Palladio. 2 Vols.

Shelf.	*No.*	
AK.	1.	Nesfield's Mediæval Architecture. 1862.
	2.	Norman Shaw's Sketches on the Continent. 1858.
	3.	Specifications of New Foreign Office. G. G. Scott.
	4.	Academy of Design. P. B. Wight. 1866.
	5.	Cottages for the Laborer. Wood. 1792.
	6.	Grüner's Terra Cotta Work in Italy. 1867.
	7–11.	Architectural Association Sketch Book. London, 1868–1873.
AL.	1.	Ungewitter. Zeigel-und-Stein arbeiten.
	2.	" Gothischen Mödels.
	3.	" Mittelaltlicher ornamentik.
	4.	Brick Construction. Degen.
AM.	1–3.	Edifices Publics en France. 3 Vols. 1825–1850.
	4–8.	L'Architecture Privée. 5 Vols. Daly. 1864.
AN.	1–7.	L'Art pour tous. Lieber. 7 Vols.
	8.	Ecole des Beaux-Arts. Vogel. 1795.

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ENVOI DE ROME. *The Antiquities of Cori.* Mr. Emmanuel Brune.

1. Details of the Temple of Hercules and of that of Castor and Pollux, in line, with the dimensions.
2. Corinthian Capital from Temple of Castor and Pollux, with Base and Architrave. One-half full size.
3. Doric Entablature of Temple of Hercules, with Capital and Base; one-quarter full size.
4. Doorway of the same, one-tenth full size.
5. Frontispiece. Various Fragments, one-quarter full size.
6. The Doric Order of the Temple of Marcellus. Copy of the original of Mr. André.

GRAND PRIX DE ROME. *1st Accessit.*

A Monastery. Mr. Felix Escalier.

7. Ground Plan.
8. Principal Elevation.
9. Section of the church, showing the decoration.
10. Perspective. Bird's Eye View.
11. Study of Plan for the same. Mr. Adrien Forget.

PROJETS RENDUS.

The House of a Sculptor. Mr. Albert Tissandier.

12. Plans.
13. Principal Elevation.
14. Rear Elevation.
15. Section.

A Hippodrome, with Stables. Mr. Escalier

16. Plans.
17. Elevation.
18. Section.

An Italian Villa. Mr. Escalier

19. Plan with Gardens.

20. Second Plan and Section.
21. Elevation.

A Hospital for Women. Mr. Forget.

22. Plans.
23. Elevation.
24. Section.

A Church. Mr. Eugene Létang.

25. Plan.
26. Elevation.
27. Section.

A Small Museum. Mr. Létang.

28. Plan, with grounds.
29. Elevation.
30. Section.

An Hotel-de-Ville. Mr. Létang.

31. Two Plans and Sections.
32. Elevation.

A Palais d'Industrie. Mr. Létang.

33. Plan.
34. Section.
35. Elevation.

A Mairie. Mr. Létang.

36. Plan.
37. Section.
38. Elevation.

An Archiepiscopal Palace. Mr. Forget.

39. Plan.
40. Elevation.

A Museum of Natural History. Mr. Létang.

41. Plans.
42. Elevation.
43. Section.

PROJETS DE DECORATION.

A Ball Room. Mr. Escalier.

44. Section.

A Pulpit and Canopy. Mr. Forget.

45. Elevation. (Sketch in India Ink.)

PROJETS D'ORDRE.

A Flower Market in the Tuscan Order. Mr. Escalier.

46. Plan Section and Elevation, in line.
47. Detail of the Order.
48. Frontispiece. Perspective View.

A Peristyle in the Corinthian Order. Mr. Létang.

49. Plan and Section.
50. Elevation.
51. Frontispiece. Detail of the Order.

An Academy of Music in the Ionic Order. Mr. Létang.

52. Plan and Section.
53. Elevation.
54. Frontispiece. Detail of the Order.

The Same. Mr. E. Calinaud.

55. Elevation.

PROJETS DE CONSTRUCTION.

A Restaurant at a Railway Station. Construction Générale. Mr. Létang.

56. Plan and Elevations.
57. Woodwork.
58. Ironwork.
59. Stonework.

A Church. Construction Générale. Mr. Victor Hoyot.

60. Plan and Elevations.
61. Details on larger Scale.
62. Woodwork.
63. Stonework.
64. Ironwork.

A Salle de Pas Perdus. Construction en Fer. Mr. Létang.

65. Plan and Elevation.
66. Section and Details.
67. Details.

OTHER LARGE ARCHITECTURAL DRAWINGS.

Six Competition Drawings for a Church at Lille. Mr. Calinaud.

68. Plan.
69. Front Elevation.
70. Side Elevation.
71. Rear Elevation.
72. Longitudinal Section.
73. Transverse Section.

74. Pavilion of the Old Louvre.
75. Interior of a Modern English Church.
76. Design for a Lighthouse. Mr. Rozier and Mr. Létang.
77. Design for an Observatory. Mr. Létang.

Large Prints.

1. Fac Simile of Perspective View of a Greek Temple. Mr. Viollet-le-Duc.
2. Fac Simile of Perspective of the Baths of Caracalla. Mr. Viollet-le-Duc.
3. Fac Simile of Original Drawing of Front of Cologne Cathedral. One-half size.
4. Fac Simile of Original Drawing of Front of St. Stephen' at Vienna.
5. Bird's Eye View of Paris, in 1845.

DEPARTMENT OF ARCHITECTURE. CASTS.

Green Room (Library).

1. Roman decorated moulding. Pantheon.
2. " " "
3. " " " "Jupiter Tonans."
4. " " "
5. Fragment of Colossal Pilaster, from the Villa Medicis.
6. Leaf from the same.
7. Roman Acanthus. Vatican.
8. Another. Rome.
9. Another.
10. Greek Bas Relief. Fragment of Vase.
11. Another.
12. Portion of Greek Scroll. Athens.
13. Roman Acanthus.
14. " Cymatium, decorated.
15. French " " Paris.
16. Acanthus, from Nature.
17. Gothic Capital from Notre Dame.
18. Another.
19. Roman Rosette. Paris.
20. " " Rome.
21. Hand.
22. Fist.
23. Three colossal Ears.
24. Eagle's Head. Rome.
25. Eye, and part of Nose.
26. Another.
27. Female hand.
28. Foot.

29. Ram's head from Candelabra, Vatican.
30. Another. Modern.
31. Bunch of Grapes.
32–40. Casts of Fruit.
41–44. Casts of Fruit and Leaves.
45, 46. Casts of Leaves and Flowers.
47. Lion's Leg.
48. The same, beneath the Skin.
49. Roman Egg and Dart Moulding. Temple of Jupiter Tonans.
50. Greek Egg and Dart Moulding.
51–55. Five Greek Anthemions, from Funeral Monuments.
56–61. Six " " from Terra Cotta Cornices.
62–64. Three Pilaster Capitals. Roman.

RED ROOM.

Casts from Angel Choir, Lincoln Cathedral; round the top of the Room.

65. Angel with Scroll.
66. Virgin and Child. Angel bearing Censer.
67. Christ showing his Wounds. Angel bearing a Soul in a Napkin.
68. Angel with Censer.
69. Angel with Lute.
70. Angel with Scroll and Palm-branch.
71. Angel with Lute. (Duplicate of 59.)
72. Angel with Falcon.
73. Angel bearing a Soul in a Napkin.
74. Angel crowned, with Harp. (? King David.)
75. Angel with closed Book.
76. Angel with open Book.
77. Angel with Viol and Bow.
78. Angel with Scroll.
79. Portion of Arch. Moulding below Spandrels, with Woman's Head as Corbel.
80. The same, with Head of a Lady.
81. " with Head of a Man.
82–103. Twenty-two similar Heads of Priests, Women, Negroes, Men, and Fools.
104–107. Four Carved Bosses.
108–113. Six Square Pieces of Foliage.

South side of Room. Gothic Sculpture and Carvings.

114. Group. King and Queen. Lincoln.
115. " Doctors Disputing. "
116. " Lady and Courtier, with Lap Dogs. Lincoln.

117–121. Five Grotesque Heads. French.
122. Carved Head in Stone. Modern.
123. " Wood. "
124. Small Head and Moulding. Southwell.
125. Corbel, with Mask and Foliage, from Palace of Louis IX.
126. Colossal Head of the Virgin, from Central Doorway, Rheims Cathedral.
127, 128. Angels with Musical Instruments. Notre Dame, Paris.
129, 130. Angels with Candle-sticks. St. Denis.
131. "*Vierge à la Coquille*," from Choir of Notre Dame, outside.
132. Colossal Head of the Prophet Ezekiel, Rheims Cathedral.
133. Corbel with Mask and Foliage, from Palace of Louis IX.
134, 135. Gargoyles, from Notre Dame.
136. Statuette. Nanthilde, St. Denis.
137–139. Three Misereres. Rouen.
140. Corbel with Angels singing.
141. Statuette. St. John.
142. Head. Godfrey de Bouillon.
143. Angel from Arch of Doorway, Notre Dame.
144. Censer. Notre Dame.
145. Triptych.
146. Censer. Chartres.
147–150. Four Monks, from Tombs of Dukes of Burgundy, Dijon.
151. Sitting Monk. Amiens.
152. Moulding with Lily.
153. Ivy.
154. Foliage.
155. Grotesques and Foliage. Flamboyant.
156. Foliage. Flamboyant.
157, 158. Weeping Monks. "*Pleureurs de Bourges*," from the Monument of Jean, Duc de Berri.
159–164. Six Casts from Ivory Carvings.
165–169. Five Panels from North Doorway of Rouen Cathedral.
170–172. Three Sculptured Crosses. Chartres.
173, 174. Two Sculptured Corbels.
175. Hands holding Book. Chartres.
176. Another.
177, 178. Sculptured Embroidery. Chartres.
179–187. Nine Heads from Choir Screen. Chartres.
188, 189. Foliage from Southwell Minster.
190. Mistletoe, Lizard and Snake. French.
191. Boy Climbing. French.

192, 193. Two Spandrels, with Foliage. Southwell Minster.
194, 195. Two Spandrels, with Figures.
196. Panel from Tomb of St. Firmin. Amiens.
197. Imp, from wall at side of the Choir. Lincoln.
198–207. Ten Angels, in panels, with Musical Instruments.
208. Three panels, with similar angel.
209. Figure from Niche. Man and Dog.
210. Figure from Niche.
211–217. Seven Bosses from Cloisters of Lincoln Cathedral. (The originals in Wood.)
218. Panel with Quatre-foils.
219. Spandrel with Foliage.
220. Spandrel with Half-figure.
221. Spandrel with Bat, from Choir and Screen. Notre Dame.
222. Spandrel with Grape-vine. Notre Dame.

West side of Room.

223–224. Byzantine Capitals from Bonn.
225. Byzantine Scroll. Man and Animals. Bonn.
226. " Men Fighting. "
227. Byzantine Panel.
228. Another.
229, 230. Two Capitals from Aix-la-Chapelle.
231. Large Capital from Moissac.
232. Small Byzantine Capital.
233. Large Byzantine Arch Moulding. Germany.
234–235. Two small Byzantine Capitals.
236–237. Two Fragments of Byzantine Columns.

238. Pilaster with Scroll. Chartres.
239, 240. Two Crockets from Notre Dame.
241. Crocket.
242, 243. Two Poppy Heads.
244, 245. Two small Corbels. Notre Dame.
246. Panel. Fleur-de-lys. Notre Dame.
247. Gothic Leaf.
248. Leaf.
249–266. Eighteen Fragments of French Gothic Foliage.
267–280. Fourteen Small Gothic Capitals. French.
281–284. Four Small Spandrels, Carved. French.

North side of Room. Gothic Carvings.

285, 286. Two Capitals from Notre Dame. (Duplicates of 17 and 18.)
287, 288. Two Capitals from Aix la Chapelle. (Duplicates of 229, 230.)
289. Capital from Lincoln.
290. Crocket Foliage.
291. Clustered Capital.
292. Boss from Notre Dame.
293. Capital from the Sainte Chapelle.
294. Corbel from Noyon.
295. Boss.
296. Capital from the Sainte Chapelle.
297. Corbel from Palace of Justice. Paris.
298. Boss from the Sainte Chapelle.
299. Double Capital from Notre Dame.
300. Boss. French.
301. Capital from Temple Church.
302. Boss. French.
303. Perforated Foliage from Arch. From Door to N. Aisle of Choir, Lincoln.
304. Fragment of Iron-Work. Notre Dame.
305. Panel Foliage with Crocket, Chartres.
306, 307. Two Crockets.
308. Flamboyant Clustered Bases.
309–311. 3 Cornice Mouldings with Crockets.
312. Moulding with Grape Leaves. Notre Dame.
313–316. Large Mouldings, with Foliage.
317. Moulding with Fig Leaves. Ste. Chapelle.
318, 319. Moulding with Foliage, two Pieces. Notre Dame. Porte St. Anne.
320. Small Base, with Toes.
321–323. 3 large Toes, from Bases.
324. Toes from Double Base.
325, 326. Two Small Panels with Foliage.
327–331. Five Pieces of Diaper-work. Foliage.
332–335. Four " " from Lincoln.
336. Fragment of Early English Foliage.
337. Panel with face.
338–340. Three Pieces of Tudor Flower.
341. Enriched Early English Moulding.
342. Gothic Arch Moulding, with Foliage.
343. Small Niche with Corbel and Canopy.
344–351. Nine bits of Moulding.

352–357. Six Pieces of Foliage.
358. Fragment of Corbel.
359–366. Eight Capitals from Chapter House. Southwell.
367–374. Eight Clustered Capitals. Southwell (?)
375. Misereres. The Resurrection, with Mary Magdalen and the Gardener.
376. The Good Samaritan.
377. King's Head, with Tudor Flowers on the Crown and Collar of Fleur-de-lys.
378. King on Throne, between two Griffins.
379. The Ascension.
380. The same, with Angels swinging Censers.
381. Duplicate of 375.
382, 383. Knight and Four Dragons. (Duplicates.)
384, 385. Samson and the Lion. (Duplicates.)
386, 387. Elephant and Castle. (Duplicates.)
388. Duplicate of 379.
389. Finial from the Cantilupe Chantry, Lincoln.
390, 391. Two Decorated Niches, with Figures. Southwell.

East side of Room. Greek and Roman Sculpture.

392. Mask of Venus of Arles.
393. Mask of Jupiter.
394. Mask of Caracalla.
395. Venus of Milo (reduction).
396. Minerva. (From Bronze.)
397. Victory. (From Bronze.)
398. Euterpe (reduction). Louvre.
399. Head. Bacchante.
400. Head. Neapolitan Psyche.
401. Head of "*Joueuse d'osselets.*"
402. Head of Somnus. (From Bronze.) London.
403. Head of Indian Bacchus (reduction).
404. Faun of the Capitol (reduction).
405. Germanicus (reduction). Louvre.
406. Silenus and Bacchus (reduction). Louvre.
407. Faun Piping (reduction). Vatican. Janus Head.
408. Head of Jupiter Trophonius. (From Bronze.)
409. The "*Joueuse d'osselets*" (reduction).
410. Fates from Parthenon (reduction), restored.
411. Muse (reduction).
412. Apollo Musagetes (reduction).

413. Muse (reduction).
414. Plato. (Terra Cotta, Bronzed.)
415. Caracalla. " "
416. Socrates. (Terra Cotta, Bronzed.)

14 Casts from small Antique Bronzes.

417. Dancing Girl.
418. Etruscan Figure.
419. Jester.
420. Cæsar.
421. Jupiter.
422. Antinous.
423. Boxer.
424. Flute-player.
425. Antinous.
426. Meleager.
427. Theseus.
428. Ball-player.
429. Gladiator.
430. Hercules.
431. Two Masks.
432. Horse's Head from Parthenon.
433. Eagle, from the Vatican.

GRAY ROOM.

South side of Room.

434. Bas Relief. Griffin. Vatican.
435. Honey-suckle Ornament from Pompeii.
436. Scroll.
437. Patera. Temple of Jupiter Tonans.
438, 439. Two small Rosettes.
440. Base Moulding. From Pedestal of Trajan's Column.
441. Chain Ornament.
442. Foliage.
443–450. Eight Rosettes from Tomb of the Scipios.
451. Acanthus Foliage.
452. Greek Moulding.
453. Moulding and Lion's Head. Metapontus.
454–473. Twenty Slabs from the Frieze of the Parthenon. (Reductions).
474–482. Nine Duplicates of the above.
483, 484. Group of Orpheus and Eurydice. (Duplicates.) (Reduction.)
485–501. Seventeen Pieces. The whole Frieze of the Choragic Monument of Lysicrates, representing Bacchus transforming the Pirates into Dolphins.

503–504. Three Acanthus Leaves.
505. Flower.
506. Flower with Pine Cone.
507. Flower with Poppy-head.
508. Flower from Capital of Temple of the Sibyl Tivoli.
509. Egyptian Bas Relief.
510. " " Head of Cleopatra.
511. Egyptian Bas Relief.
512. Scroll from Choragic Monument.
513. Scroll from Tomb of the Scipios.
514. Roman Acroterium. Villa Pamphili Doria.
515. Renaissance Pilaster.

West side of Room.

516. Capital of Antæ. Minerva Pollas.
517. Ionic Volute. Athens.
518. Horse's Head. Vatican.
519. Corinthian Capital. Modern.
520. The same. Pilaster Capital.
521. Horse. By Bailey.
422. Eagle. By Bailey.
523, 524. Acroteria from Parthenon. (Duplicates.)
525. Corner Capital from Erechtheum.
526, 527. Capital of Antæ, Erechtheum. (Duplicates.)
528. Architrave and Door Cap. Erechtheum.
529. Support of Table. Pompeii.
530. Renaissance Panel.
531. Another.
532. Leg to Table with Lion's Head and Foot. Capitol Museum.
Two Casts from Terra Cotta. Campana Collection.
533. Bacchante, Faun, and Infant Bacchus.
534. Castor and Pollux.
535, 536. Two Renaissance Medallions.
537. Colossal Head of David. Michael Angelo.
538. Cast of Greek Acroterium. Athens.

North side of Room.

539. Capital from Alhambra.
540. Moorish Panel.
541. Pilaster. Chateau de Gaillon.
Four Casts from Terra Cotta. Campana Collection.
542. Two Priestesses.
543. Scroll-work with Winged Victory.

544. Paris and Helen.
545. Helen and Menelaus.
546. Renaissance Bracket. Vatican.
547, 548. Two Modillions. Modern.
549. Console. Modern.
550. Honeysuckle Ornament.
551. Another, from the Erechtheum.
552. Another.

Eleven small Bas Reliefs.

553. Bacchanal and Panther.
554. Corybantes dancing. Vatican.
555. Faun dancing.
556. Mercury and part of a Group. Louvre.
557. Bacchus and Three Fauns.
558. Faun dancing.
559. Smaller figure, like No. 558.
560. Faun dancing. Villa Albani.
561. Pastoral Group.
562. Victory and Bull. Vatican.
563. Greek Inscription.
564. Large Alto Relievo, from end of the Vienna Sarcophagus.
565–572. Eight Acanthus Leaves. Modern.
573. Fragment of Cornice.
574, 575. Two Pilaster Panels.
576. Another.
577. Capital of Pilaster, same as No. 541.
578. Large Acanthus Leaf.
579, 580. Two Sets of small Rosettes. Modern.
581, 582. Two Guilloche Mouldings.
583. Set of Enriched Mouldings. Modern.
584. Profile Head. Full Size. Trajan's Column (?)
585. Head from Arch of Titus.
586. Another.
587. Two others.
588. Group from Trajan's Column. Four Soldiers.
589. Another. Soldier watering his Horse.
590. Upper part of Group. Five Soldiers going into battle.
591. " " Four Barbarian Captives.
592. " " Six Roman Citizens.
593–633. Forty-one Heads from Trajan's Column.
Soldiers, Citizens, Barbarians, Women and Horses.
634. Alto Relievo of the Battle of the Amazons, from a Sarcophagus at Vienna.

East side of Room. French Renaissance.

635, 636. Doric Capital and part of Rusticated Pilaster. Louvre.
637. Lion's Head, from the Hotel Carnavelet. Jean Goujon.
638. Pilaster Capital, with part of Enlablature.
639. Frieze, with Laurel Leaves. Chateau de Gaillon.
640. Key-stone, enriched. Chateau de Gaillon.
641. Lion's Head, from Nature. Bussy.
642–645. Four Capitals from Tomb of Louis XII. St. Denis.
646. Lioness' Head, from Nature. Bussy.
647. Door Knocker. Louis XIV.
648. Cartouche Frieze. Door of St. Maclou, Rouen.
649. Cartouche, with Cupid. Door of St. Maclou, Rouen.
650. Mask of Pan. Louvre.
651. Lion's Head.
652. Rosette. Modern.
653. Anatomical Figure by Michael Angelo.
654. Bracket.
655. Slave by Michael Angelo. Statuette.
656. Bracket with Cupid.
657. Head of Michael Angelo's Slave. Louvre.
658. The same reduced.
659–666. Six Pilaster Panels.
667, 668. Two Small Pilasters from Tomb of Louis XII. St. Denis.
669. Small Figure of a Lion. Rouillard.
670. Another, smaller.
671. Tiger. Rouillard.
672. *Écorché*, Horse. Bonheur.
673. " Man. Houdon.
674, 675. Two others. Coudron.
676. Mask. Pan.
677. Head. Nondescript. Modern.
678. Statuette. Milo of Crotona.
679. Bracket. (Duplicate of No. 654.)
680. Prisoner, by Michael Angelo. Statuette.
681. Bracket, with Cupid.
682. Mask of the Virgin, by Michael Angelo.
683. Statuette by Pradier. Woman carrying Water.
684. Bust by Pradier.
685–688. Four Pilasters from Tomb of Louis XII.
689. Figure from Tomb in the Church at Brou. The Virgin.
690. Another.
691. Another. St. Elisabeth.

692. Wing.
693. Bust of Diane de Poictiers. Jean Goujon.
694–697. Casts of Four small Vases.
698–702. Casts of Five Shells.
703. Mask.
704. Another.
705. Duplicate of No. 677.
706–708. Three small Cupids by Fiammingo.
709, 710. Two others, in Alto Relievo, larger, supporting a Cartouche.
Two Bas Reliefs from the Chateau d'Anet. Jean Goujon.
711. Angel with the Cross.
712. Angel with the Pillar.
713. Infant, from the lid of the Vase containing the Heart of Francis I. St. Denis. Jean Goujon.
714. Bas Relief from Tomb of Francis I. St. Denis.
715. Cupid from Court of the Louvre. Jean Goujon.
716, 717. Two heads by Fiammingo.
718. Small Capital.
719. Panel with Fleur-de-lys.
720. Panel with Crescent.
721, 722. Two Panels with Arabesque Griffins. St. Maur, near Paris.
723. Woman's Hand, from Nature.
724. Colossal Renaissance Hand.
725–728. The Four Seasons. Casts from the Terra Cotta Models of the Sculptures of the Fountain in the Rue de Grenelle. Bouchardon.
729, 730. Two Panels. Rome.
731. Head of John the Baptist. Donatello. Baptistry. Florence
732–743. Twelve Vases, Casts from the Hildesheim Treasure.
744–746. Three Fragments of Casts of Central American Sculpture.

Stained Glass.

First Screen.

Ruth in the Cornfield. Messrs. Morris & Co., London.
Head of David. Messrs. Lyon & Co., London.
Virgin and Child, in Canopy. Messrs. Lavers & Barraud. London.
Medallion, with Head of Milton. The same.
Two Panels of Quarry Work. The same.
One Panel of Mosaic Work, in Color. The same.
Two Panels with Flowers. Messrs. Heaton, Butler & Bayne, London.
Grisaille of Rolled Glass. The same.

Second Screen.

Two specimens of Grisaille work. Messrs. Cottier & Co., Glasgow.
Figure of Architecture. Messrs. Cook & Co., Boston.
Two grisaille panels, with medallions. The same.

Third Screen.

Two pieces consisting of fragments. Ancient English work.
Specimen of Heraldric work. Messrs. Heaton, Butler & Bayne.
Mosaic of Rolled glass. The same.
Grisaille of Rolled glass. The same.
Grisaille with small head. Messrs. Lavers & Barraud.
Two specimens of quarry-work. The same.

Fourth Screen.

Grisaille work. Messrs. Clayton & Bell, London.
Four Medallions with Angels. The same.
Five Medallions set in Grisaille work. Messrs. G. E. Cook & Co., London.
Two small panels.

TILES, TERRA COTTA, ETC.

Four large Specimens of Mosaic, Encaustic and Majolica tilework, by Messrs. Maw & Co. Broseley.
Two Hundred other Tiles. The same.
Six Tiles, illustrating Æsop's Fables. Messrs. G. E. Cook & Co., Lond.
Four of Painting and the Graces. The same.
Four pieces of Painted Tile Work. Messrs. Simpson & Co.
One Hundred Neapolitan Tiles.
Sixteen Ancient Tiles from Chapter House, Salisbury.
Twenty-four Modern Reproductions of Pompeiian Vases.
Three Modern Neapolitan Cups.
Seventeen small Copies of Statuary in Terra Cotta.
Two Specimens of Salviati's Venetian Mosaic.

MODELS.

Models of the Five Orders of Vignola, with Entablatures and Pedestals, by Brucciani.
Five Models belonging to the Boston Athenæum.
The Unitarian Church at Baltimore, showing Dome and Pendentives.
The Parthenon.
Shakespeare's House at Stratford.
Two smaller Models.
Model of a Dwelling House.

Three Models in Cork.
The Temple of Neptune at Poestum.
The Temple of the Sibyl at Tivoli.
An Etruscan Tomb.
Two Models of Window Finish.
Model of Door, and Door Finish.
Twenty Models of Joinery, published by the Frères Chrétiens.
Six [illegible] of Framing, " " "

MISCELLANEOUS ARTICLES.

Thirty-six specimens of Ornamental Woods.
Thirty-six Specimens of Italian and other Marbles.
Small specimen of Pompeian Decoration.
Fragment of Opus Reticulatum.
Fragments of Roman Bricks.
Fragment of Vaulting Stone from Salisbury Cathedral.
Three Specimens of Scotch Granite, polished.
Specimen of Béton Coignet.
Specimen of Ransome's Patent Stone.
Large Wooden Corinthian Capital from Brattle Street Church.
Console and Modillions from the same.

LECTURE DIAGRAMS.

1. Elementary Mouldings.
2. Proportions of the Five Orders.
3. " " Tuscan Order.
4. " " Doric Order.
5. " " Corinthian Order.
6. Origin of Doric Order.
7. The Roman Doric Order.
8. Another. "
9. The Greek Doric Order.
10. Another. "
11. The Roman Ionic Order.
12. The Greek Ionic Order.
13. Assyrian Bas Relief.
14. Persian Capitals.
15. Lycian Tomb.
16. Another.
17. Another.
18. Another.

19. Egyptian Capital. Colored.
20. Assyrian Ornament. "
21. Another.
22. Roman Vaulting.
23. Early Gothic Vaulting.
24. Lierne Vaulting. Oxford Cathedral.
25. Fan Vaulting. Peterborough Cathedral.
26–29. Four Diagrams of Gothic Vaulting. Plans.
30. Three Half-timbered Houses.
31. French Gothic Capital.
32. Gothic Mouldings.
33. Gothic Bases.
34. Architectural Map of Greece, with the Colonies.
35. " Map of Italy.
36. " Map of France.
37. " Map of England.
38–40. Three Diagrams of Curvilinear Perspective.
41. General Diagram of the Perspective of Planes.
42. " " " Perspective of Shadows.
43–70. Diagrams of the Frères Chrétiens.
71–76. Six Cartoons for the Stained Glass in the First Church. Messrs. Lavers & Barrand.
77–79. Three Cartoons for the Stained Glass in the First Church. Messrs. Heaton, Butler & Bayne.
80, 81. Two Cartoons for the Stained Glass in the First Church. Messrs. Lyon & Co. and Saunders & Co.

FOURTEEN PAINTED DIAGRAMS LOANED BY THE LOWELL INSTITUTE.

1. Elementary Lines.
2. Trusses.
3. Egyptian Capitals and Columns.
4. Façade of Temple of Apollinopolis Magna.
5. Section through the Parthenon.
6. St. Paul's, *extra muros*. Rome. Interior.
7. Salisbury Cathedral, from the S. W.
8. Gothic Doorway and Capitals.
9. St. Peter's. Rome.
10. Villa Capra, near Vicenza.
11. Pompeian Palace. Vicenza.
12. English Manor House.
13. Christ Church. Cambridge.
14. Trinity Church. New York.

SUMMARY OF THE COLLECTIONS OF THE DEPARTMENT OF ARCHITECTURE.

378 Books.
2240 Photographs.
465 Card Photographs.
660 Stereoscopic Views.
260 Glass Slides.
810 Drawings.
963 Prints and Lithographs.
77 Drawings from the Ecole des Beaux-Arts, etc.
746 Plaster Casts.
35 Specimens of Stained Glass.
32 Architectural Models.
95 Lecture Diagrams.
Also Tiles, Terra Cotta, and various miscellaneous articles.

First Church.

First Church.

First Church.

L INSTITUTE.

ALUMNI OF THE INSTITUTE.

The degree is Bachelor of Science (S. B.) in the department of I, Civil and Topographical Engineering; II, Mechanical Engineering; III, Mining Engineering; IV, Architecture; V, Chemistry; VI, Metallurgy; VII, Natural History; VIII, Physics; IX, Science and Literature; X, Philosophy. Present residence and occupation are given, so far as known.

Graduates in 1868.

Ellery C. Appleton, III, Allentown, Pa. Engineer for Lehigh Coal and Navigation Co.

Nelson W. Conant, III, Columbus, Indiana. Farmers' Bank.

Frank R. Firth, I, Deceased.

Eli Forbes, IX, Clinton, Mass. Chemist at Lancaster Mills.

Charles C. Gilman, III, Marshalltown, Iowa. Chief Engineer, Central Railroad of Iowa.

Charles E. Greene (A.M., Harv. Coll.), I, Ann Arbor, Mich. Professor of Civil Engineering, University of Mich.

Albert F. Hall, II, Charlestown, Mass. Draughtsman at G. F. Blake Manufacturing Co., Boston.

William E. Hoyt, I, Boston, Mass. Instructor in Civil Engineering and Stereotomy, Mass. Inst. Tech.

Robert H. Richards, III, Jamaica Plain, Mass. Professor of Mining Engineering, Mass. Inst. Tech.

Walter H. Sears, I, Plymouth, Mass. Civil and Hydraulic Engineer, Boston.

Charles A. Smith, I, St. Louis, Mo. Professor of Civil and Mechanical Engineering, Washington University.

Joseph Stone, I, Manchester, N. H., Agent Manchester Mills.

Bryant P. Tilden, III, Philipsburg, Montana. Practising Assayer.

James P. Tolman, III, Boston, Mass. Supt. Silver Lake Co. for manufacturing steam packing, etc.

Graduates in 1869.

William H. Baker, Helena, Montana. Chief Draughtsman, Surveyor General's Office.

Howard A. Carson, I, Providence, R. I. Assistant Engineer, Providence Water Works.

J. Rayner Edmands, II, Boston, Mass. Practising Mechanical Engineer.

William R. Nichols, V, Boston, Mass. Professor of General Chemistry, Mass. Inst. Tech.

Channing Whitaker, II, Lowell, Mass. Professor of Mechanical Engineering, Mass. Inst. Tech.

Graduates in 1870.

Edward K. Clark, II, Boston, Mass. Assistant Engineer Mass. State Board of Health.

Charles R. Cross, IX, Jamaica Plain, Mass. Professor of Physics and Descriptive Astronomy, Mass. Inst. Tech.

Russell H. Curtis, I, Boston, Mass. Civil Engineer, 12 West St.

Charles W. Hinman, III, Boston, Mass. State Inspector of Gas and Gas-Meters.

Sampson D. Mason, I, Logansport, Indiana. Treasurer and Chief Engineer, Detroit, Eel River and Illinois R.R.

N. Frederic Merrill, V, Cambridgeport. Supt. of the Boston Works of the Boston and Colorado Smelting Co.

Theodore F. Tillinghast, I, New Bedford, Mass. Private business.

Edmund K. Turner, I, Marblehead, Mass. Civil Engineer, in employ of Fitchburg R.R.

Daniel W. Willard, II, Jamaica Plain, Mass. Sheep raising in Wyoming Territory.

L. F. J. Wrinkle, III, Virginia City, Nevada. Surveyor General's Office.

Graduates in 1871.

Foster E. L. Beal, I, Ames, Iowa. Professor of Civil Engineering, State Agricultural College.

Addison Connor, (A. B., Tufts Coll.), I, South Framingham, Mass. Boston Water Works.

Henry M. Cutler, I, San José, Cal. Not heard from.

Elmer Faunce, III, Kingston, Mass. Out of employment.

Edward H. Foote, I, Somerville, Mass. Practising Civil Engineer.

Frank L. Fuller, I, Grantville, Mass. Civil and Hydraulic Engineer, 7 Exchange Place, Boston.

Henry M. Howe (A. B., Harv. Coll.), III, Boston. Travelling in Europe on professional business.

Albert H. Howland (A. M., Amherst Coll.), I, Boston, Mass. Civil Engineer, 12 West St.

G. Russell Lincoln, III, Steel Works P. O., Pa. Chemist of Pennsylvania Steel Works.

William A. Pike, I, Orono, Maine. Professor of Civil and Mechanical Engineering, Maine State College.

George H. Pratt, V, South Boston, Mass. Supt. Bayside Alkali Works.

Edward W. Rollins, III, Golden, Colorado. Resident Engineer and Cashier Col. Central R.R. Co.

Walter W. Smith, II, Dayton, Ohio. Manufacturer of Steam Pumps and Hydraulic Machinery.

Charles F. Stone, III, Waltham, Mass. Student at Law.

Almarin Trowbridge, Jr., II, Charlestown, Mass. Unemployed.

Isaiah S. P. Weeks, I, Charlestown, Mass. Office of T. and J. Doane, Civil Engineers.

Randal Whittier, V, Boston, Mass. Instructor in Mathematics, Boston University.

Graduates in 1872.

Calvin Francis Allen, I, Providence, R. I. Assistant Engineer, Providence Water Works.

Benjamin E. Brewster, III. Not heard from.

William B. Dodge, I, Beverly, Mass. Engineer's Office, State Lunatic Asylum, Danvers, Mass.

Frederic A. Emmerton, V, Joliet, Ill. Chemist of Joliet Iron and Steel Co.

J. Amory Herrick, V, Nashua, N. H. Supt. of Steel department of Nashua Iron and Steel Co.

James M. Hodge, III, New York. Assistant Engineer Erie Railway.

Bradford H. Locke, III, Central City, Colorado. Mining Engineer and U. S. Deputy Surveyor.

Charles S. Minot, V, Germany. Student of Natural History.

Walter Shepard (A. B., Harv. Coll.), I, Harrison Sq. Assistant Engineer Boston and Albany R. R.

Richard S. Soule (A. B., Harv. Coll.), II, Altoona, Pa. Mechanical Engineer's Office, Motive Power Department, Penn. R.R.

Clarence S. Ward, III, Boston, Mass. Lawyer, 35 Court St.

Graduates in 1873.

Amory Austin (A. B., Harv. Coll.), V, 40 Kilby St., Boston. Not heard from.

George W. Blodgett, I, Boston, Mass. Boston Water Works.

William E. Brotherton, I, Cincinnati, Ohio. Bookkeeper, Bank of Gilmore, Dunlap & Co.

Samuel A. Fabens, Jr., I, Deceased, March 14, 1875.

Samuel M. Felton, Jr., I, Pittsburg, Pa. Gen. Supt. Pittsburg, Cincinnati and St. Louis Railway Co.

Frederick L. Fisher, I, Medway, Mass. In business (Fisher & Taylor).

Clarence L. Howes (A. M., Amherst Coll.), I, Hanover, Mass. Not heard from.

Frederic Guild, Jr., IX, Boston, Mass. In Leather Business.

William D. Harris, I, Boston, Mass. Unemployed.

William A. Kimball, II, 38 Park Row, N. Y. N. Y. Belting and Packing Co.

William C. May, V, Boston, Mass. Student.

Frank B. Morse, I, Boston, Mass. Instructor of Drawing, M. I. T., and Warren Academy, Woburn.

George Phillipps, III. Not heard from.

Henry A. Phillips, IV, Chicago, Ill. Studying abroad.

Robert A. Shailer, I, Chicago, Ill. Engineer in employ of American Bridge Co.

Charles E. Stafford, III, Steel Works P. O., Penn. In charge of Open Hearth Steel department of Pa. Steel Works.

Ellen H. Swallow (Mrs. R. H. Richards) (A. M., Vassar Coll.), V, Jamaica Plain.

S. Everett Tinkham, I, Boston, Mass. City Engineer's Office.

Frank W. Very, V. Not heard from.

Webster Wells, I, Boston, Mass. Instructor in Mathematics and Descriptive Geometry, M. I. T.

Randal Whittier, S. B., I, Boston, Mass. Instructor in Mathematics, Boston University.

Francis H. Williams, V, Boston, Mass. Student, Harvard Medical School.

Louis F. Wood, V, Boston. Supt. Color Manufactory, Wellesley.

Graduates in 1874.

Herbert Barrows, I, Reading, Mass. Employed in Civil Engineering.

George H. Barrus, II, Reading, Mass. Engaged with Mr. George B. Dixwell upon experiments on cylinder condensation.

William T. Blunt, I, East Somerville, Mass. Draughtsman for Boston Harbor Commission.

George E. Doane, I, Middleboro, Mass. Observer U. S. Coast Survey.

William B. Dowse, IV, Boston, Mass. Not heard from.

Joseph S. Emerson, I, West Newton, Mass. Newton Water Works.

Elliot Holbrook, I, Providence, R. I. Teacher of Mechanical Drawing, etc., Warner's College.

Aechirau Hongma, I, Tokio, Japan. Government Engineer.

Charles P. Howard, I, Hartford, Ct. J. L. Howard & Co., Railway and Car Builders.

Frank H. Jackson, III, Boston, Mass. A. Jackson & Son, dealers in Fertilizers and Chemicals.

Willis H. Myrick, II. Died, Oct. 17, 1875.

Herbert B. Perkins, I, Monson, Mass. Teacher of Mathematics and Physics, Monson Academy.

Frank H. Pond, II, Dayton, Ohio. Assistant Supt. Brownell and Kielmeier Manufacturing Co.

Edward S. Shaw, I, Cambridge, Mass. Pursuing advanced professional studies, partly at M. I. T.

Francis H. Silsbee, II, Manchester, N. H. Draughtsman at Manchester Mills.

Arthur W. Sweetser, I, So. Williamstown, Mass. Teacher in Greylock Institute.

Robert C. Ware, IX, Salem, Mass. Student in M. I. T.

Stephen H. Wilder, IX, Cincinnati, Ohio. In Rolling Mill.

GRADUATES IN 1875.

Samuel E. Allen, I, South Framingham, Mass. Boston Water Works.

James L. Arnott, X, Thompsonville, Ct. Not heard from.

Amos J. Boyden, IV, Foxborough, Mass. Draughtsman for Stone & Carpenter, Architects, Providence, R. I.

Moses D. Burnett, III, Syracuse, N. Y. Student in Medicine.

H. K. Burrison, I, East Boston, Mass. Draughtsman for Park Commissioners, and Sec. Boston and Northwestern R. R. Co.

Christopher A. Church, I, Woonsocket, R. I. Woonsocket Woolen Mills.

Frank S. Dodge, I, Beverly, Mass. In employ of Gen. Thom., U. S. Engineer, Portland, Me.

Edgar S. Dorr, I, Mt. Auburn, Mass. Unemployed.

William C. Edes, I, Bolton, Mass. Engineering work for Bureau of Statistics of Labor.

Charles W. Goodale, III, Boston, Mass. Boston and Colorado Smelting Works.

Edward A. W. Hammatt, I, Newton Centre, Mass. Unemployed.

Edward A. Handy, I, Boston, Mass. South Boston Flats Improvement.

James H. Head, II. Died August 18, 1875.

Thomas Hibbard, II, West Roxbury, Mass. Draughtsman, Atlantic Works, E. Boston.

William F. Huntington, I, Springfield, Mass. Bookkeeper, Chester Paper Co., Huntington, Mass.

Leonard P. Kinnicutt, V, Worcester, Mass. Studying in Europe.

J. Austin Knapp, II, Boston, Mass. Assistant in Mechanical Engineering, Inst. of Tech.

Wilfred Lewis, II, Phil., Pa. At William Sellers & Co., Machine Works.

Samuel J. Mixter, VIII, Boston, Mass. Student, Harv. Medical School.

Benjamin A. Oxnard, III, Brooklyn, N. Y. Assistant Supt. and Chemist Fulton Sugar Refinery.

Thomas D. Plimpton, II, Walpole, Mass. Student at Law.

William A. Prentiss, IX, Holyoke, Mass. Wire Manufacturing.

Francis T. Sargent, II, Malden, Mass. Assistant in Mechanical Engineering, Mass. Inst. Tech.

William H. Shockley, III, New Bedford, Mass. Resident Graduate Mass. Inst. Tech.

James B. Stanwood, II, Cincinnati, Ohio. Apprentice in R. R. Machine Shop.

H. L. J. Warren, III, Ore Knob, Ash Co., N. C. Metallurgist, Ore Knob Copper Co.

William R. Webster, III, Coshocton, Ohio. Coal Inspector for the Pittsburgh, Cincinnati and St. Louis Railway Co.

William F. Sargent, I, Sargentville, Maine. Unemployed.

LIST OF MEMBERS

OF THE

SOCIETY OF ARTS

OF THE

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,

SEPTEMBER 30, 1875.

HONORARY MEMBER.

* Prof. Daniel Treadwell, Cambridge, Mass.

LIFE MEMBERS.

Allen, Stephen M. . Boston.
Amory, William . . "
Atkinson, Edward . "

Baker, William E. . "
*Bancroft, E. P. . "
*Beebe, James M. . "
Bigelow, E. B. . . "
Bowditch, J. I. . . "
Bowditch, Mrs. J. I. "
Brimmer, Martin . "
Browne, C. Allen . "
Bullard, W. S. . . "

Colby, Gardner . . "
Cummings, John . . Woburn.

Dalton, Chas. H. . Boston.
Davenport, Henry . "
Dupee, James A. . "

Edmands, J. Wiley . "
*Eldredge, E. H. . "
Emerson, George B. "
Endicott, Wm., Jr. . "

Fay, Joseph S. . . "
Fay, Mrs. Sarah S. . Boston.
Forbes, John M. . . "
Forbes, Robert B. . "
Foster, John . . . "

Gaffield, Thomas . . "
*Gardner, G. A. . . "
Gardner, John L. . "
Gookin, Samuel H. . "
*Grant, Michael . . "
Greenleaf, R. C. . . "
Grover, Wm. O. . . "

Hemenway, Mrs. M. "
Hoadley, J. C. . . Lawrence.
*Huntington, Ralph . Boston.

Johnson, Samuel. . "

Kidder, Henry P. . "
Kuhn, Geo. H. . . "

*Lawrence, James . "
Lee, Henry . . . "
Lee, John C. . . . "
* Lee, Thomas . . "

* Deceased.

Little, James L. . . Boston.
Lowell, John A. . . "
Lyman, Geo. W. . "

Matthews, Nathan . "
McGregor, James . "
Mudge, E. R. . . . "

Nichols, Lyman . . "
Norcross, Otis . . "

*Pierce, Carlos . . Canada.
Preston, Jonathan . Boston.
Pratt, Mrs. William . "
Pratt Miss . . . . "

Richardson, Geo. C. . "
*Richardson, J. B. . "
Rogers, Henry B. . "
Rogers, William B. . "
Ross, M. Denman . W. Roxbury.
Ross, Waldo O. . . "

Ruggles, S. P. . . Boston.
*Savage, James . . "
Sayles Henry . . "
Sayles, Mrs. Willard "
*Sears David . . "
Shaw, Mary S. . . "
*Skinner, Francis . "
*Stetson, Joshua . "

Thayer, Nathaniel . "
Thorndike, John H. . "
Tobey, Edward S. . "
*Turner, J. M. . . "

*Upton, George B. . "

Walcott, J. H. . . "
Wales, Geo. W. . . "
Wales, T. B. . . . "
Wales, Miss . . . "
*Whitney, Joseph . "

ASSOCIATE MEMBERS.

Adams, James . . Charlestown.
Ames, Isaac . . . Boston.
Amory, T. C. . . . "
Anderson, Luther W. Quincy.
Appleton, Thos. G. . Boston.
Atkinson, Chas. F. . "
Atkinson, Wm. P. . "
Atwood, Nat'lh E. . Provincet'n.
Austin, Edward . . Boston.

Barber, Lyman L. . Charlestown.
Barnard, James M. . Boston.
Batchelder, John M. Cambridge.
Beal, James H. . . Boston.
Bender, Richard W. "
Bigelow, A. O. . . "
Bigelow, Jacob . . "
Bishop, Chas. J. . . "
Blaney, Henry . . "
Bôcher, Ferdinand . "
Bolles, M. Shepard . "
Bond, George W. . W. Roxbury.
Bond, W. S. . . . "
Boott, William . . Boston.
Bourne, William . . "

Bouvé, T. T. . . . Boston.
Bowditch, Ernest W. Brookline.
Bowditch, Wm. I. . "
Browne, Causten . . Boston.
Buckingham, C. E. . "

Cabot, Edward C. . "
Cabot, Samuel . . "
Carey, A. C. . . . "
Carpenter, Geo. O. . "
Carruth, Charles . "
Clapp, Wm. W. . . "
Clarke, E. H. . . "
Clinch, John M. . . "
Cummings, Nath'l . "
Curtis, Frederick . "

Dana, Edward A. . "
Danforth, I. W. . . "
Danforth, James H. . "
Davies, Daniel . . "
Davis, Barnabas . . "
Davis, F. J. . . . Waltham.
Delano, Jos. C . . New Bedford.
Denny, Henry G. . Boston.

Dewson, F. A. . . Boston.
Dix, John H. . . . "
Dixwell, J. J. . . . "
Doane, Thomas . . "
Dresser, Jacob A. . "
Dunklee, B. W. . . "

Eastman, Ambrose . "
Eliot, Charles W. . Cambridge.

Farley, Noah W. . Boston.
Farmer, Moses G. . "
Fitch, Jonas . . . "
Flint, Charles L. . "
Forbes, Franklin . Clinton.
Francis, James B. . Lowell.
Fuller, H. Weld . . Boston.
Fuller, Horace W. . "

Gardner, James B. . "
Gibbens, Joseph M. . "
Grandgent, L. H. . "
Guild, Chester . . "
Guild, Henry . . "

Hall, Andrew T. . "
Hall, Thomas . . . "
Hamblet, James . . "
Haven, Franklin. . "
Hayes, S. Dana . . "
Heard, John T. . . "
Henck, John B. . . Brookline.
Henshaw, John A. . Cambridge.
Hewins, Edmund H. Boston.
Hilton, William . . "
Holmes, O. W. . . "
Homans, C. D. . . "
Houghton, Charles . "
Hubbard, Charles T. "
Hyde, George B. . "
Hyde, Henry D. . "

Jackson, J. B. S. . "
Jasper, Gustavus A. . "
Jenks, Lewis E. . . "

Kehew, John . . . "
Kneeland, Samuel . "

Lamson, Chas. D. . "
Langley, H. P. . . "
Lanza, Gaetano . . "
Lawrence, A. A. . "

Lee, Francis L. . . Boston.
Lee, Thomas J. . . "
Leuchars, R. B. . . "
Lewis, Charles W. . Charlestown.
Lewis, Wm. K. . . Boston.
Lincoln, F. W. . . "
Little, James L., Jr. "
Little, John M. . . "
Lothrop, Sam'l K. . "
Lowe, N. M. . . . "
Lowell, John . . . "
Lyman, Theodore . Brookline.

Mansfield, A. K. . . Boston.
Markoe, G. F. H. . "
Marshall, H. N. F. . "
Mason, Robert M. . "
May, F. W. G. . . Dorchester.
May, John J. . . . "
McBurney, Charles . Boston.
McMurtrie, Horace . "
McPherson, W. J. . "
Merrill, N. F. . . Cambridgep't.
Montgomery, Hugh . Boston.
Moore, Alex. . . . "
Morse, John T. . . "
Morse, Samuel T. . "
Munroe, William . "

Nichols, James R. . Haverhill.
Norton, Jacob . . Boston.

Ordway, John M. . W. Roxbury.

Page, Edward . . Boston.
Page, W. H. . . . "
Parsons, Wm. . . "
Paul, J. F. . . . "
Peabody, O. W. . . "
Perry, O. H. . . . "
Philbrick, Edward S. "
Philbrick, John D. . "
Pickering, E. C. . "
Pickering, H. W. . "
Plumer, Avery . . "
Pope, Edward E. . "
Prang, Louis . . . "
Pratt, George W. . "
Pratt, T. Willis . . "
Putnam, J. P. . . . "

Quincy, Edmund . Dedham.
Quincy, Josiah . . Boston.

Revere, Joseph W.	Boston.
Rice, Alexander H.	"
Richards, R. H.	"
Ritchie, E. S.	Brookline.
Robbins, James M.	Milton.
Robinson, J. R.	Boston.
Rotch, Benj. S.	"
Royce, H. A.	"
Ruggles, John	"
Runkle, John D.	Brookline.
Russell, LeBaron	Boston.
Salisbury, D. Waldo	"
Sawyer, Edward	Newton.
Sawyer, Timothy T.	Charlestown.
Sears, Philip H.	Boston.
Shedd, J. Herbert	"
Sherwin, Thos.	Dedham.
Shimmin, Chas. F.	Boston.
Shurtleff, A. M.	"
Sinclair, Alex. D.	"
Smith, Chauncy	Cambridge.
Snow, S. T.	Boston.
Sonrel, Antoine	Winchester.
Sprague, Chas. J.	Boston.
Stackpole, G. W.	"
Stevens, Benj. [illegible]	"
Stimpson, Fr[illegible]	"
Storer, Fran	"
Strater, Her	"
Sturgis, John H.	"
Sullivan, Richard	"
Thompson, Wm. H.	Boston.
Trowbridge, John	Cambridge.
Tufts, John W.	Boston.
Tuxbury, Geo. W.	"
Upham, J. B.	"
Urbino, S. R.	"
Walworth, J. J.	"
Ware, Chas. E.	"
Ware, Wm. R.	"
Warren, Cyrus M.	Brookline.
Warren, Geo. W.	Boston.
Warren, Joseph H.	"
Warren, Sam'l D.	"
Waters, C. H.	Clinton.
Watson, R. S.	Milton.
Watson, Wm.	Boston.
Weston, David M.	"
Whipple, Edwin P.	"
Whitaker, Channing	Lowell.
Whitman, Herbert T.	Boston.
Whitmore, Wm. H.	"
Whiton, David	"
Wilder, Marshall P.	Dorchester.
Williams, H. W.	Boston.
Winthrop, Robert C.	"
Wright, John H.	"
Wyman, Morrill	Cambridge.
Zalinski, E. L.	Boston.

PREPARATION FOR ADMISSION.

Preparation for Admission.—In order to afford to instructors and others a somewhat definite idea of the requirements for admission to the school, the following statements and suggestions are made.

Arithmetic. — The candidate will be expected to be familiar with the ordinary operations of arithmetic in both simple and compound numbers, with common and decimal fractions, with the computation of interest, etc. In the metric system a general knowledge will be required of the origin and advantages of the system, of the manner of designating the multiples and divisions of the units of length, capacity, etc., and especially of the relation existing between the measures of weight and those of length and capacity. Ability to perform ordinary arithmetical problems in the metric system will be required, but no stress will be laid upon the conversion of the ordinary United States weights and measures into the corresponding values of the metric system; as, however, the metric weights and measures are used constantly immediately on the students' entering upon the work of the school, practical familiarity with them is very desirable.

Geography. — A good elementary knowledge of the motions of the earth, of the mathematical measurements and divisions of its surface, and of the outlines of physical and political geography is required. The candidate for admission should be able to correctly define any of the principal physical features of the earth's surface, such as peninsulas, gulfs, etc.; he should be able to locate and describe the chief natural and political divisions, and the most important mountain chains, river-systems, etc. A more complete knowledge of North America and Europe is expected than of the other continents, but minute details and statistics, such as the lengths of rivers and heights of mountains, are not required. Practice in free-hand map draw-

ing from memory is earnestly recommended, and proficiency in the art will receive the merit it so justly deserves.

The following may serve as an illustrative example of the nature of the questions the candidate is expected to answer.

1. Define latitude — North Temperate zone — mountain — ocean — border-sea — kingdom — republic — state — town.
2. Draw rapidly an outline map of South America, making it as complete as time will permit.
3. Draw a map of the State, Province, or country where you reside, representing as many of its features as you conveniently can.
4. In what latitude is New York city? What countries, cities, or seas of the Eastern World have nearly the same latitude?
5. Give a geographical description of Italy. Also one of the State of New York.
6. In what sections of the United States is cotton an important agricultural product?
7. To which race do the Japanese belong? Give some idea of the national character of the French.
8. What is the capital of Kansas? of Georgia? of Holland?
9. Give the boundaries of the States of Kentucky, California and Connecticut. Where is Mount Shasta? Name the great mountain regions of the globe.

English Grammar. — In English Grammar, candidates must be able to distinguish at sight between the several parts of speech, and to give the proper inflections of nouns, pronouns, adjectives, and verbs; especially the comparison of irregular adjectives, the principal parts of irregular verbs, and, in all verbs, the exact forms corresponding to the distinctions in mood and in tense. Particular attention should be paid, in preparing for the Institute, to distinguishing prepositions from conjunctions, and subordinate conjunctions from co-ordinate. The same is true in regard to demonstrative, indefinite, relative, and interrogative pronouns.

Candidates must also know how to classify terms (whether single words or phrases) into substantives and attributives, and must be familiar with the subdivisions of substantives into sin-

gulars, generals, and universals. They must have a good degree of skill in separating sentences into subject, copula, and predicate; and, in case these terms are complex, must know how to separate them into base and determinant, and how to tell whether the determinant *changes* the meaning of the base or merely *unfolds* it. In case the meaning is *changed*, they must be able to show whether the modifiers are objective, or signify some other relation, *e. g.*, time, place, cause, comparison or possession.

In regard to all the foregoing matters, teachers should aim to secure *practical skill in applying the distinctions to examples*, rather than a mere knowledge of their definitions. *In the examination for admission, this skill in practice will be made the vital point.*

[The less familiar of the foregoing distinctions may be defined as follows: —

A *singular* term is one that denotes absolutely but one object of a kind, whether that object be a solitary individual or a solitary group of individuals. A singular may therefore be either a proper or a collective noun, or any phrase equivalent to either. For example, Julius Cæsar, London, this city, the committee, the cities of the plain.

A *general* term is one that denotes more than one object of a kind, but less than all the possible members of it. It may do this either (1) by naming any one of them *indeterminately* (as *man, a man, some man or other*), or (2) by naming several *distributively* (as *men, some men, five men*), or (3) by naming *all* within certain limits — all the *actual* cases as contrasted with all *possible* cases (as *men*, in the sense of *most men* or *all men hitherto* or *all men now living*). For example, cities, all the continents, the continents.

A *universal* term is one that denotes absolutely all the objects of a kind, *i. e.*, all *possible*, future as well as present and past. For example, truth, the true, duty, the beautiful, space, time, causality, all triangles, every circle.

The *base* of a complex term is that word, or combination of words, in it that expresses the starting-point of the thought denoted by the whole term. For example, man, in the term "good man"; good man, in the term "every good man."

The *determinant* of a complex term is the word, or combina-

tion of words, added to the base, and characterizing it. For example, good, in the term "good man"; every, in "every good man"; of all times, in "the wise and good of all times."

All the other distinctions mentioned above, are to be taken according to the customary usage in treatises on grammar.]

English and American History. — The examination in this subject will be upon the period of the American Revolution beginning with the accession of George III.; and a better and more thorough knowledge of this portion of history—but rather of the causes of the revolution and the lives and characters of the chief actors than a minute acquaintance with the details of military transactions, will be expected than can be obtained from the mere study of the names and dates of a school compendium.

Rhetoric. — In Rhetoric the examination will be confined to those parts of any school manual which give the rules for the construction of sentences and treat of the qualities which characterize a good style. The object of this examination will be to test the candidate's ability to write good English, and as a preparation for it, *practice* in English composition is strongly recommended in preference to the study of the remaining portions of the Rhetorics.

French. — The essential part of the *French requirement for admission* to the school is the grammar, or knowledge of the forms and structure of the language, and we would offer with this in view the following suggestions in regard to the preparatory study.

a. The *verb* should be made the main study, and the other parts of speech in proportion to the closeness of their relation to the same.

b. The *regular conjugations* should be mastered before taking up the study of the irregular ones, and so of the other regular forms and usages as compared with the exceptions and idioms.

c. Next to the verb in importance comes the pronoun, particularly the *personal pronoun*, the form and value of which depends mainly upon its relation to the verb, whether as sub-

ject, direct object, *dative*, or as connected by a preposition, a careful analysis alone eliciting the specific relation in each case; hence the importance of a thorough analytical training.

d. The amount of *reading matter* is not so much for the sake of the knowledge of words and its intrinsic value, as to afford a sufficiently wide field for exercise in analysis and the discrimination of forms, quality being more important than quantity, and accuracy essential.

e. In regard to pronunciation, it is more important that the student have an accurate conception of the nasal, e, é, è, and u sounds, the connection of words, and the division into syllables, than greater fluency with less accuracy.

English Literature.—The examination will be upon the literary history of the latter part of the Eighteenth and the early part of the Nineteenth century. The candidate will be expected to be familiar with the names and general character of the leading writers of that period, and to show an acquaintance, from actual reading, with some portion of its literature.

Algebra.—Besides possessing ability to perform ordinary algebraic operations, the candidate must be able to solve simple and quadratic equations with two or more unknown quantities, and must understand theoretically and practically the involution of algebraic expressions, the extraction of square and cube root, fractional and negative exponents and radicals.

Besides readiness in the solution of examples, it is important that the student should be well drilled in the principles involved and be able to state them clearly and concisely. For example, besides ability to solve readily a quadratic equation, he should also be familiar with the few fundamental properties of the quadratic roots, and particularly with the conditions upon which equal and imaginary roots depend.

While the theory of logarithms is not at present required, it is extremely desirable that students should early become familiar with their use, and teachers are earnestly advised to put into their hands Professor J. M. Peirce's four place tables, or Bowditch's five place tables, or Bremiker's six or seven place tables, and show them how much time familiarity with their use will

soon enable them to gain in all numerical work. Nor need this be a blind use; for as soon as the student understands what an exponent is, and that the multiplication, division, the involution and the evolution of numbers are affected by the addition, subtraction, multiplication and division of exponents, he has only to learn that the exponent is a logarithm, to use the tables intelligently.

Geometry. — In plane and solid (including spherical) geometry, the amount contained in the standard text-books on the subject will be required; and care should be taken to apply all propositions, which find frequent use, to numerical examples.

LOWELL FREE COURSES OF INSTRUCTION.

1865-1866.

1. *Elementary Mathematics.* Eighteen lectures, by Professor Runkle.
2. *Descriptive Geometry.* Eighteen lectures, by Professor Watson.
3. *Chemistry of the Non-metallic Elements.* Eighteen lectures, by Professor Storer.
4. *The Metals.* Eighteen lectures, by Professor Eliot.
5. *English Language and its Literature.* Eighteen lectures, by Professor Atkinson.
6. *French.* Eighteen readings, by Professor Bôcher.

1866-1867.

1. *Chemical Manipulations.* Thirty practical lessons, by Professors Storer and Eliot.
2. *Mathematics.* Eighteen lessons, by Professor Runkle.
3. *Navigation and Nautical Astronomy.* Eighteen lessons, by Professor Osborne.
4. *Elementary French.* Eighteen lessons, by Professor Bôcher.
5. *Grammar, Rhetoric and Composition.* Ten lessons, by Professor Atkinson.

1867-1868.

1. *Geometry and Trigonometry.* Eighteen lessons, by Professor Osborne.
2. *Calculus.* Eighteen lessons, by Professor Runkle.
3. *Elementary German.* Eighteen lessons, by Instructor Kraus.
4. *Chemical Manipulations.* Thirty lessons, by Professor Storer.
5. *Natural History.* Ten lessons, by Professor Kneeland.
6. *Languages and General Grammar.* Ten lessons, by Professor Atkinson.

1868-1869.

1. *Qualitative Chemical Analysis.* Thirty lessons, by Professors Eliot and Storer.
2. *Mining, and the Mineral Resources and Deposits of the United States.* Eighteen lectures, by Professor Rockwell.
3. *English History and Literature.* Eighteen lectures, by Professor Atkinson.
4. *Comparative Physiology and the Laws of Life.* Eighteen lectures, by Dr. Kneeland.
5. *French.* Eighteen lessons, by Professor Bôcher.

1869–1870.

1. *Outlines of Zoology.* Eighteen lectures, by Dr. Kneeland.
2. *Mineral Resources of the United States.* Ten lectures, by Professor Rockwell.
3. *Elementary Algebra and Trigonometry.* Eighteen lectures, by Professor Osborne.
4. *Sound.* Ten lectures, by Professor Pickering.
5. *English History and Literature.* Eighteen lectures, by Professor Atkinson.
6. *Mechanical and Machine Drawing.* Twenty-four lessons, by Instructor Schubert.

1870–1871.

1. *Elementary French.* Eighteen lessons, by Professor Böcher.
2. *Physiology and Hygiene.* Eighteen lectures, by Professor Kneeland.
3. *Descriptive Geometry applied to the Arts, with corresponding exercises in Mechanical Drawing.* Fifteen lectures, by Professor Watson.
4. *General Chemistry.* Fifteen laboratory lectures, by Assistant Professors Richards and Nichols.
5. *Qualitative Analysis.* Fifteen laboratory exercises, by Assistant Professors Nichols and Richards.
6. *Modern History and Literature.* Eighteen lectures, by Professor Atkinson.

1871 1872.

1. *English Writers of the 18th and 19th Centuries.* Ten lectures, by Professor Atkinson.
2. *Progressive Development of Life in the Geological Ages.* Eighteen lectures, by Professor Kneeland.
3. *Elementary German.* Eighteen lessons, by Instructor Krauss.
4. *Elementary French.* Eighteen lessons, by Instructor Lévy.
5. *Elementary Chemistry.* Twenty lectures, by Professors Richards and Nichols.
6. *Experimental Chemistry.* Twenty-four laboratory exercises, by Professors Richards and Nichols.
7. *Experimental Physics.* Twenty-four laboratory exercises, by Professor Pickering.

1872–1873.

1. *Chemical and Physical Geology.* Eighteen lectures, by Professor T. Sterry Hunt.
2. *Experimental Mechanics.* Eighteen lectures, by Professor Cross.
3. *Modern History.* Ten lectures, by Professor Atkinson.

4. *Logic with special reference to its connection with English Analysis.* Ten lectures, by Professor Howison.

5. *Laws of Life and Health.* Ten lectures, by Professor Kneeland.

6. *Systematized French Pronunciation, French Conjugation, Idiomatic French.* Eighteen lectures, by Instructor Lévy.

7. *Translation of Lessing's Nathan der Weise, with a Philological and Critical Commentary.* Eighteen lectures, by Instructor Krauss.

8. *Elements of Descriptive Geometry.* Eighteen lectures, by Instructor Lanza.

9. *Machine Drawing.* Eighteen lessons, by Professor Schubert.

1873–1874.

1. *Logic. An Examination of the system of J. S. Mill.* Eighteen lectures, by Professor Howison.

2. *Sound.* Eighteen lectures, by Professor Cross.

3. *Machine Drawing* for advanced students. Twenty-four exercises, by Instructor Schubert.

4. *Elementary Descriptive Geometry.* Eighteen lectures, by Professor Lanza.

5. *Chemistry: Qualitative Analysis.* Twenty-four laboratory exercises, by Professor Nichols.

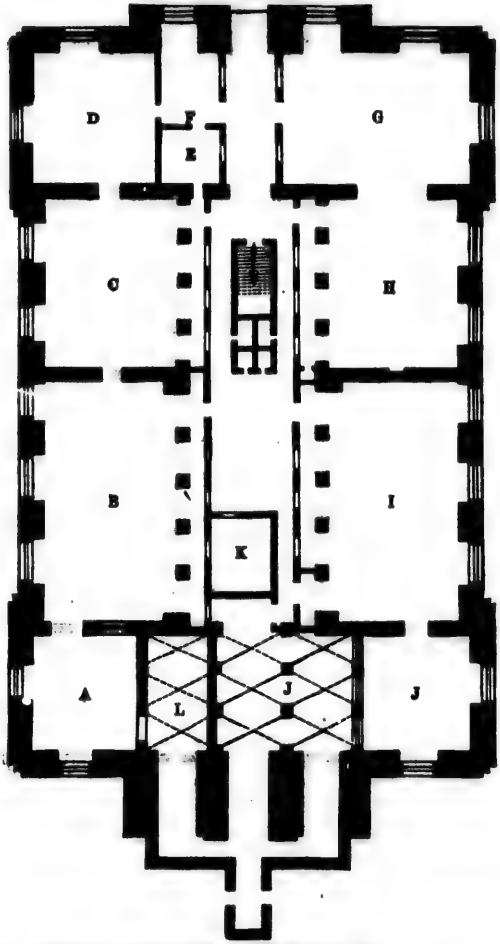
6. *Architectural History and Design.* Eighteen lectures, by Professor Ware.

7. *Elementary German.* Eighteen lessons, by Instructor Krauss.

1874–1875.

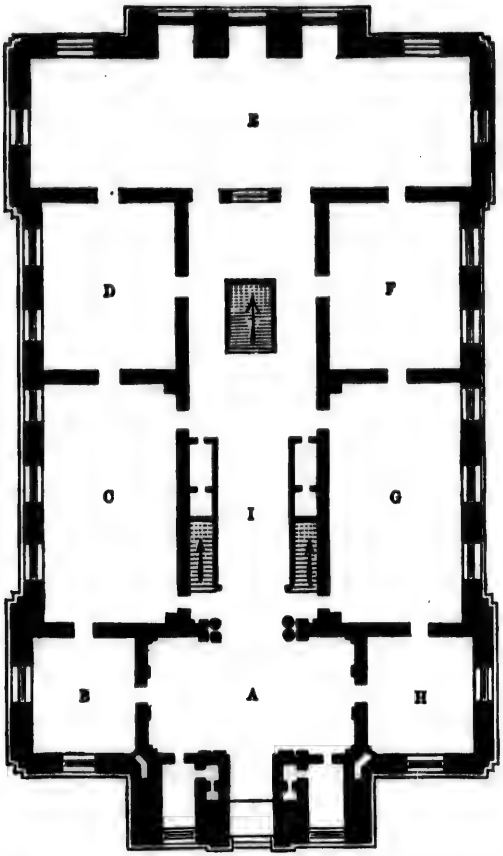
For reports upon the Courses of 1874–75, see pp. 94–104.

BASEMENT FLOOR.



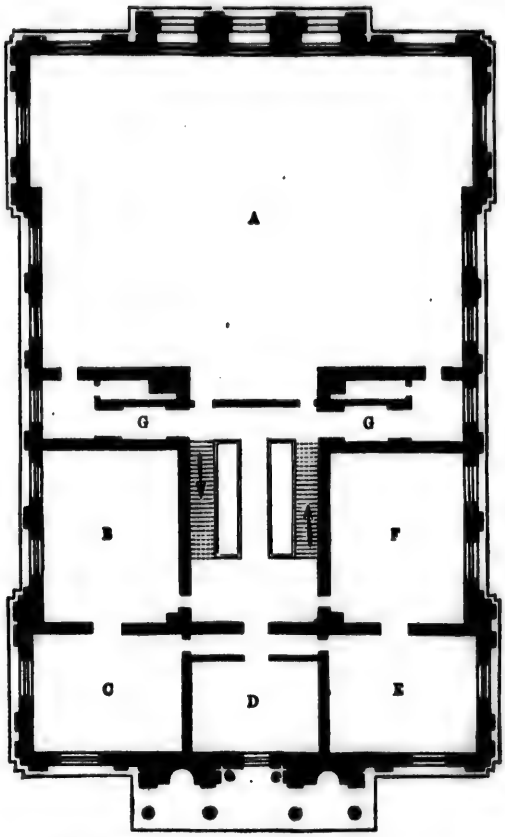
A. Professors' Chemical Laboratory, 25′ 0″ by 22′ 11″.
B. General and Qualitative Chemical Laboratory, 49′ 7″ by 24′ 0″.
C. Quantitative Chemical Laboratory, 25′ 9″ by 24′ 0″.
D. Quantitative Chemical Laboratory, 26′ 4″ by 24′ 0″.
E. Balance Room, 8′ by 12′.
F. Professor Wing's Private Laboratory, 16′ 0″ by 12′ 0″.
G. Mining Laboratory, 40′ 2″ by 21′ 10″.
H. Metallurgical Laboratory, 25′ 9″ by 24′ 0″.
I. Chemical Lecture Room, 49′ 7″ by 24′ 0″.
J. J. Mechanical Engineers' Laboratory, 25′ 0″ by 69′ 1″.
K. Daily Chemical Supply Room, 14′ 6″ by 12′ 0″.
L. Boiler Room, 15′ by 25′ 0″.

FIRST STORY FLOOR.



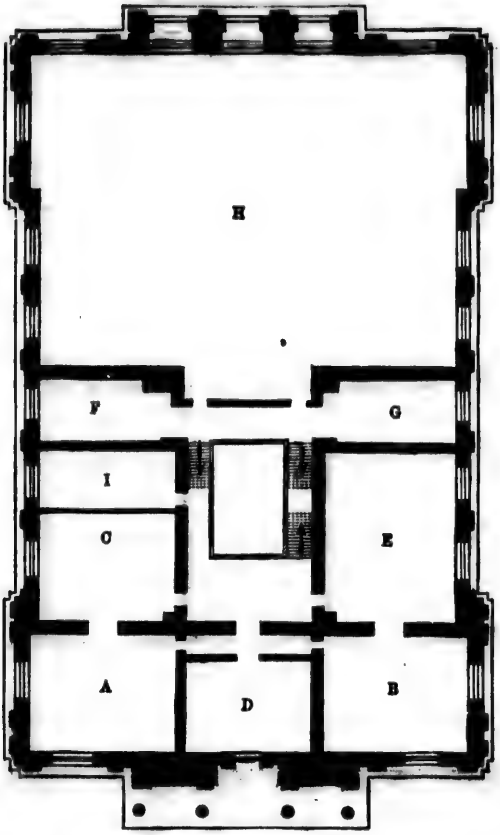
A. Entrance Hall, 49′ 2″ by 25′ 0″.
B. President's Office, 25′ 0″ by 23′ 11″.
C. Physical Lecture Room, 49′ 7″ by 29′ 3″.
D. Physical Laboratory and Apparatus Room, 25′ 3″ by 29′ 3″.
E. Physical Laboratory and Apparatus Room, 93′ 0″ by 27′ 10″.
F. Geological Lecture Room, 25′ 3″ by 29′ 3″.
G. Society of Arts Room, 49′ 7″ by 29′ 3″.
H. Secretary's Office, 25′ 0″ by 23′ 11″.
I. Stairway Hall, 57′ 3″ by 29′ 10″.

SECOND STORY FLOOR.



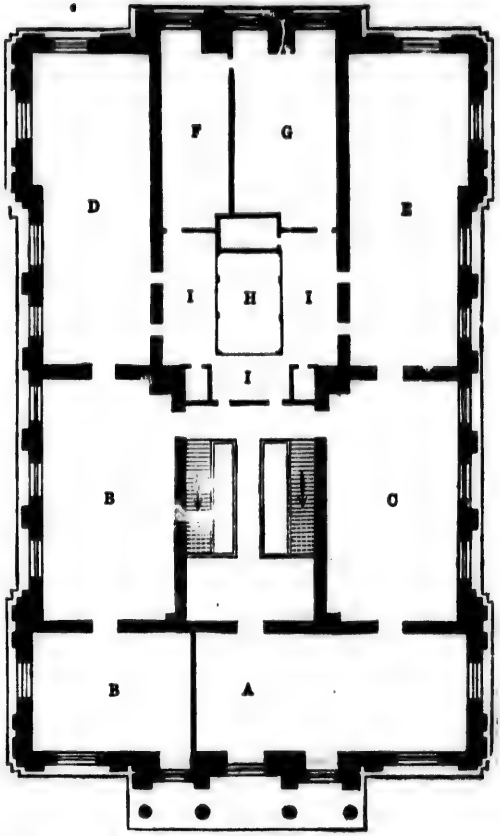
A. Huntington Hall, 93′ 0″ by 65′ 5″.
B. Mathematical Lecture Room, 34′ 9″ by 26′ 3″.
C. Civil Engineering Lecture Room, 32′ 2″ by 25′ 0″.
D. Modern Language Lecture Room, 26′ 2″ by 20′ 0″.
E. English Lecture Room, 32′ 2″ by 25′ 0″.
F. Mathematical and Astronomical Lecture Room, 34′ 9″ by 26′ 3″.
G. G. Passageways to Huntington Hall.

HALF STORY FLOOR.



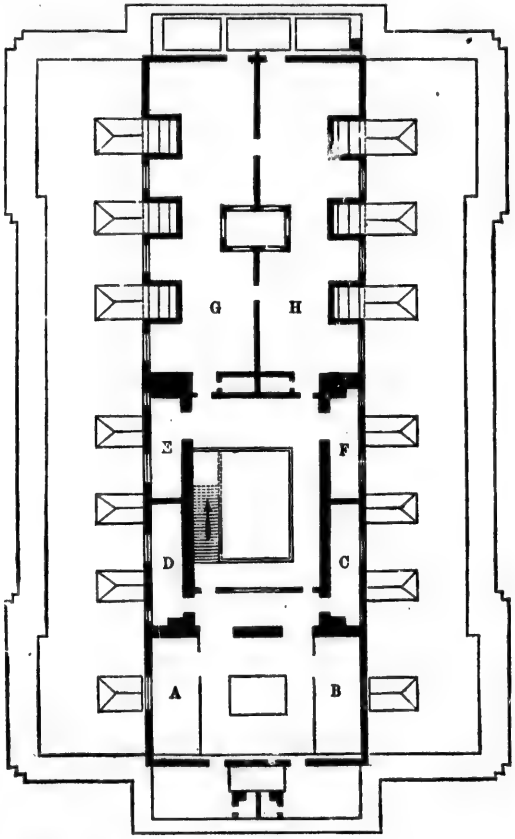
A. Architectural Museum, 29′ 2″ by 25′ 0″.
B. Architectural Library and Study Room, 29′ 2″ by 25′ 0″.
C. Architectural Museum, 29′ 3″ by 20′ 9″.
D. Natural History Lecture Room, 29′ 2″ by 20′ 0″.
E. Prof. Richards' Lecture Room, 34′ 9″ by 29′ 3″.
F. Prof. Atkinson's Study, 29′ 3″ by 14′ 2″.
G. Prof. Hunt's Study, 29′ 3″ by 14′ 2″.
H. Huntington Hall.
I. Prof. Howison's Study, 29′ 3″ by 14′.

THIRD STORY FLOOR.



A. Reading and Study Room, 69′ 0″ by 26′ 0″.
B. B. Civil Engineers' Drawing Rooms, 49′ 7″ by 29′ 9″.
C. First Year's Drawing Room, 49′ 7″ by 29′ 9″.
D. Mechanical Engineers' Drawing Room, 65′ 5″ by 29′ 0″.
E. First Year's Drawing Room, 65′ 5″ by 29′ 0″.
F. Mechanical Engineering Lecture Room, 27′ 0″ by 17′ 0″.
G. Mathematical and Descriptive Geometry Lecture Room, 27′ 0″ by 29′ 0″.
H. Model Room, 21′ 0″ by 13′ 0″.
I. I. I. Passageways.

FOURTH STORY FLOOR.



A. Prof. Lanza's and Prof. Whitaker's Study, 24′ 5″ by 11′ 6″.
B. Prof. Henck's Study, 24′ 5″ by 11′ 6″.
C. Prof. Osborne's Study, 24′ 9″ by 7′ 6″.
D. Prof. Richards's and Prof. Nichols's Study, 28′ 0″ by 7′ 6″.
E. Instructor Hoyt's Study, 21′ 6″ by 7′ 6″.
F. Prof. Ware's Study, 24′ 9″ by 7′ 6″.
G. Architects' Drawing Room, 65′ 5″ by 21′ 10″.
H. Lowell School of Design, 65′ 5″ by 21′ 10″.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

PRESIDENT'S REPORT

FOR THE

Year ending Sept. 30, 1876.

BOSTON:
PRESS OF A. A. KINGMAN.
1876.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

PRESIDENT'S REPORT

FOR THE

Year ending Sept. 30, 1876.

BOSTON:
PRESS OF A. A. KINGMAN.
1877.

Extracts from Acts of the General Court of Massachusetts, in relation to the Massachusetts Institute of Technology.

Act of Incorporation. "William B. Rogers [and others named], their associates and successors, are hereby made a body corporate, by the name of the MASSACHUSETTS INSTITUTE OF TECHNOLOGY, for the purpose of instituting and maintaining a Society of Arts, a Museum of Arts, and a School of Industrial Science, and aiding generally, by suitable means, the advancement, development, and practical application of sciences in connection with arts, agriculture, manufactures, and commerce."

Chapter 183, *Acts and Resolves of* 1861.

Grant of Public Lands. "When the Massachusetts Institute of Technology shall have been duly organized, located, and established, ... there shall be appropriated and paid to its treasurer, each year, on the warrant of the Governor, for its endowment, support, and maintenance, one third part of the annual interest or income which may be received from the fund created under and by virtue of the 130th chapter of the Acts of the 37th Congress, at the second session thereof, approved July 2, 1862 [giving Public Lands to the States in aid of instruction in Agriculture, the Mechanic Arts, and Military Science and Tactics]. . . . . Said Institute of Technology, in addition to the objects set forth in its Act of Incorporation [as above quoted], shall provide for instruction in military tactics."

Chapter 186, *Acts and Resolves of* 1863.

Power to confer Degrees. "The Massachusetts Institute of Technology is hereby authorized and empowered to award and confer degrees appropriate to the several courses of study pursued in said Institution, on such conditions as are usually prescribed in universities and colleges in the United States, and according to such tests of proficiency as shall best promote the interests of sound education in this Commonwealth."

Chapter 247, *Acts and Resolves of* 1863.

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PRESIDENT'S REPORT.

To the Corporation of the Institute:—

I deeply regret the delay in the issue of this report, which has been caused by the desire to include all matters relating to the International Centennial Exhibition held at Philadelphia during the year, and affecting the Institute. The particular cause of delay has been the time taken to prepare, in the midst of other absorbing duties, a full and accurate catalogue of the collections presented to us by exhibitors, which would have been practically useless without the systematic classification we have made, with the corresponding casing and catalogue. I shall touch upon some matters begun near the close of the year, which will be reported upon fully hereafter.

The various reports and matters herewith submitted will inform you of the condition of the several departments of the Institute for the year 1875–76. For information relating to departments not especially referred to, and in which no particular changes have taken place during the year, you will please consult the report of last year.

The changes in the corps of Instruction during the year have been the resignations of Lieut. E. L. Zalinski, Professor of Military Science and Tactics, Thomas E. Pope, A. M., Instructor in Quantitative Analysis, Frank B. Morse, S. B.,

Instructor in Free Hand Drawing, Francis T. Sargent, S. B., and J. Austin Knapp, S. B., Assistants in Mechanical Engineering, and William E. Nickerson, Assistant in General Chemistry and Qualitative Analysis. Lieut. Henry W. Hubbell, Jr., U. S. Art'y, was appointed Prof. of Military Science and Tactics, Thomas W. Robinson, S. B., Assistant in Quantitative Analysis, James B. Stanwood, S. B., and Clarence L. Dennett, S. B., Assistants in Mechanical Engineering.

Attendance. The aggregate number of students in attendance during the year was 299, an increase of 11 over the previous year. For classification and other items, see page 22 of the Secretary's report.

Graduates. The number of graduates for the year was 44, two of whom completed the course in 1872–73, with the exception of presenting a graduating thesis. This is the largest number ever graduated in one year. It will also be noticed that all but one of the ten departments are represented. The following table gives the aggregates in years and departments.

	1868	1869	1870	1871	1872	1873	1874	1875	1876	Total.
Civil Engineering . .	6	2	4	8	3	12	10	10	14	69
Mechanical Engineer'g	1	2	2	2	1	1	4	7	8	28
Mining Engineering .	6		2	5	4	2	1	6	7	33
Architecture						1	1	1		3
Chemistry		1	1	2	3	6		1	5	19
Metallurgy									1	1
Natural History . .									2	2
Physics								1	3	4
Science and Lit. . .	1		1			1	2	2	2	9
Philosophy									2	2
Total	14	5	10	17	11	23	18	28	44	170

Theses. Abstracts will be found on pp. 69–123. Mr. Galloupe's thesis has been published in full in the Journal of the Franklin Institute, and also a portion of Mr. Kilham's; those of Mr. Holman and Mr. Jacques in the Proceedings of the American Academy of Arts and Sciences; those of Mr. Barrows and Mr. Crosby have been accepted for publication in the

Proceedings of the Boston Society of Natural History; and those of Mr. Ware and Mr. Phipps, one published and the other accepted, by the Journal of Speculative Philosophy, St. Louis.

These facts are the only commentary I need make upon the general excellence of all the theses presented.

THE INTERNATIONAL CENTENNIAL EXHIBITION AT PHILADELPHIA, 1876.

The Institute's Exhibit at Philadelphia. Early in the year the question of the participation of the Institute in the Exhibition began to be agitated. There was a lack of unanimity in favor of so doing, and especially a lack of means to meet the necessary expense. These discouragements led to delay and decrease of interest, until late, and when the matter had about been given up, the State came to our aid in a small appropriation. We then hurriedly made such collections as were available, and represented as nearly as possible the current work of the school in the various departments. These collections were exhibited in the East Gallery of the Main Building, in one of the stair-ways leading to the Gallery, and in the Women's Pavilion, and were regarded by all as creditable to the school, and adding substantially to the credit and value of the State's exhibit of its educational resources and progress. The exhibit of the Lowell School of Design was thought worthy of a special award, as was also our exhibit as an whole. On application of Dr. David Murray, Commissioner of Education in Japan, the whole collection from the Lowell School of Design was presented to the Educational Museum of Japan. A recent letter from Dr. Murray speaks of these designs as a marked and interesting feature of the Museum. This Museum is mainly intended to illustrate the present condition of Industrial Art Education, and to serve in some degree to guide and stimulate such education in that country. The Catalogue of the Institute's exhibit will be found in the Appendix to this report.

The Institute's Centennial Excursion. From the beginning of our school, an important feature in the instruction of the higher classes has been the excursions to mining regions and manufacturing works relating to the various courses. This has been especially true of the mining department, which has for several years spent a portion of each long summer vacation in visits to the most important mining centres of the United States and Canadas. The students have been particularly prepared to profit by such excursions by their experience in the treatment of ores in our Mining and Metallurgical Laboratories. I may add here that these laboratories have grown from year to year in capacity and completeness of detail for doing almost all kinds of work, and on as large a scale as will ever be needed either for instruction or experiment; and they have, besides, demonstrated the feasibility of incorporating a large amount of practice in the curriculum of the school, and that, too, not only without curtailing the amount of purely scientific instruction, but by giving to this instruction point and definiteness. Contact with mines and mining operations, preceding such practical study, is of comparatively little value to the student or the mine; while the handling of ores by the ton in the laboratory particularly qualifies the student to rapidly profit by contact with the wider sphere and conditions of mining works. Besides, he begins by being an aid rather than an hindrance to the works, because he is not entirely ignorant of the elements of practice.

The success of these laboratories is beginning to show us more clearly the possibilities and advantages of such facilities in other engineering departments. There is a certain knowledge which can only come to the mind by the ability to handle the materials with which we deal, and if this training of the hand can be formulated into an educational system, and pursued by educational methods, we shall have engrafted upon our industrial education a very important and vitalizing element. The experience of the works must, as far as possible, be brought into the school in order that the training of the school

may properly and most profitably react upon the works. All the sciences and arts which find their applications in industrial works should be thoroughly taught in the schools, and there is no more difficulty in teaching the arts in a practical way, when they have once been comprehended as such, as they will be when studied as a whole, and not through some special application, than there is in teaching the sciences as such, or in their applications. But the *manual* of an art can only be formulated and taught by an expert in this art, and it is only through such a course of instruction as a basis, that we come to see the vital connection between science and art in their relations and applications in the various industries. Our system of excursions naturally led us to consider the feasibility of a trip to Philadelphia during the Centennial Exhibition. But too many were anxious to go; none of the departments which had been in the habit of arranging and conducting excursions of small parties were willing to undertake one on so large a scale. At last the Military department came to our aid. The organization which had been found necessary for properly carrying on the instruction of the department, was found sufficient to maintain order and cohesion in a much larger body, and the Institute, as well as all the members of the party, owe a debt of gratitude to Lieut. Zalinski for the energy and efficiency with which the whole affair was conducted; and it gives me great pleasure to refer you to his interesting report, where you will find full details of all matters connected with the expedition, except the presentation to Lieut. Zalinski of a valuable watch and chain by the members of the party, in recognition of his aid in planning and conducting the expedition. This presentation was also made the occasion by members of the Corporation present, as well as by professors and students, to cordially thank him for what he had done for the school in the reorganization of the Military department, in the building of a proper drill hall and gymnasium, and in the establishment of a restaurant where well cooked and well served meals could be had at a reasonable price.

I gladly take this opportunity to thank Lieut. Zalinski in behalf of the Corporation, and to wish him success in all his future duties and relations.

It was supposed that much special study would be done and reported upon by the students of the several departments. In this expectation we were to a considerable extent disappointed. While the heads of departments were able to aid their students in finding what related particularly to their work, and to guide them in a general way, the excitements and fatigue of each day left little power or desire to take full notes, and still less to write them out for the instruction or inspection of others at the end of the day. Notwithstanding this apparent, not real, failure to accomplish the result in a given way, the exhibition proved a grand lesson to all of us, and I am happy in believing that the Institute is only just beginning to reap the fruits which in succeeding years will reach greater maturity and value.

The Centennial Collections. When our party disbanded, I felt convinced that the Institute could reap an additional advantage if some one could be on the ground to gather up such materials as would in all probability be given to institutions, or sold at low rates, rather than packed and returned home at greater or less cost. Mr. A. D. Blodgett, one of the graduates of 1876, was selected for this duty. He began work July 1st, and remained in Philadelphia until the middle of December, after he had packed and shipped his collections to Boston. Since his return he has taken charge of the arranging and cataloguing the collections, the results of which you will find in the Appendix. These collections could have been made much larger and more valuable if we had had but a small sum to expend in this way. Not an article was purchased, our only expense being the packing and sending to Boston.

At the same time, Mr. Blodgett took charge of the Institute's exhibit, and distributed about 8000 copies of various catalogues and reports to individuals, and to foreign countries, through their Commissioners. It was by this means that many of the

collections were obtained, and relations were established which can not fail of continuing to be of advantage to the Institute.

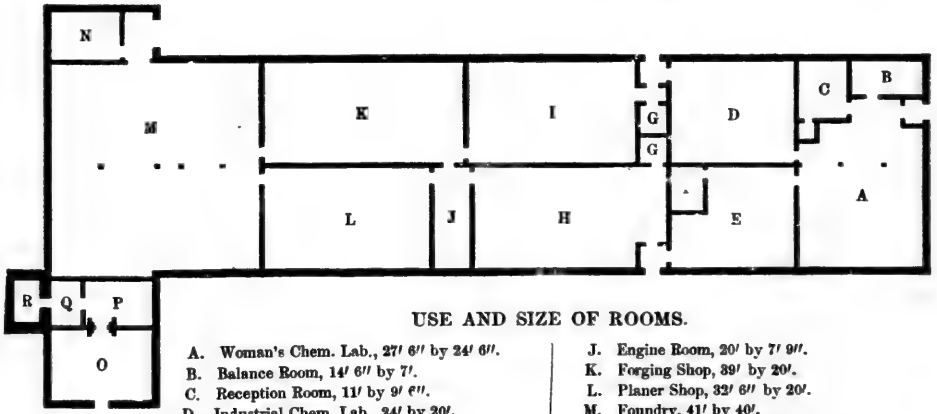
We have thus formed the nucleus of the Industrial Museum, which was a prominent feature of the Institute in its Act of Incorporation. With proper space and care this Museum would grow rapidly at a very inconsiderable annual cost. This matter deserves your serious attention.

THE NEW TEMPORARY BUILDING FOR SHOP-WORK AND ADVANCED CHEMISTRY.

The New Building. The plan of the building authorized by your vote of Aug. 17, 1876, is given on the next page. It is of one story, with 12′ brick walls, nearly flat tar and gravel roof, well lighted, heated, and ventilated, and covers 7500 sq. feet. The stem of the T, 150′×40,′ was first built, but finding greater demands upon the space than was expected, we afterwards made an addition of 75′×20′ parallel to Newbury St. Some changes in the details in the heating of the main building has given the heat and power needed in this building without any addition of boiler capacity. The funds for the erection, heating, and equipment of this building have been contributed by the Women's Educational Association, the Massachusetts Charitable Mechanic Association, and various individuals, details of which will be reported hereafter.

A. *Women's Advanced Chemical Laboratory.* With the exception of the years 1869–70 and 1872–73, chemistry has been among the Lowell Courses since their establishment in 1865–66. The instruction in this subject has been given mostly through laboratory work; and as the courses have been open to both sexes, quite a large number of women, residing in and about Boston, have been able to acquire a good knowledge of General Chemistry and Qualitative Analysis. This fact led the Women's Educational Association of Boston to apply to this Institute to furnish advanced chemical instruction to women. By your vote of May 10, 1876, such instruction was author-

NEW TEMPORARY BUILDING FOR SHOP-WORK AND CHEMISTRY.



USE AND SIZE OF ROOMS.

A. Woman's Chem. Lab., 27′ 6″ by 24′ 6″.
B. Balance Room, 14′ 6″ by 7′.
C. Reception Room, 11′ by 9′ 6″.
D. Industrial Chem. Lab., 24′ by 20′.
E. Microscopical Lab., 24′ by 20′.
F. Dark Room, Spectroscope.
G.G. Tool and Stock Rooms, 6′ by 6′.
H. Lathe Shop, 37′ by 20′.
I. Chipping and Filing Shop, 32′ 6″ by 20′.
J. Engine Room, 20′ by 7′ 9″.
K. Forging Shop, 39′ by 20′.
L. Planer Shop, 32′ 6″ by 20′.
M. Foundry, 41′ by 40′.
N. Wash Room, 13′ 6″ by 9′ 6″.
O. Organic Chem. Lab., 19′ by 14′.
P. Special Work Room, 13′ by 9′ 6″.
Q. Store Room, 9′ 6″ by 6′.
R. Ice Chamber, 8′ by 5′.

ized, provided the Association would aid in securing the funds to provide the proper laboratory and equipments. The Association promptly performed its part by raising for this purpose about $2000. The laboratory, balance and reception rooms, are devoted exclusively to women, and will accommodate about twenty students. The space devoted to this laboratory was placed in charge of Professor John M. Ordway, to whom we owe the excellent and commodious arrangements, and under whose personal supervision and instruction the department has realized the highest expectations of all concerned.

E. *The Microscopic and Spectroscopic Laboratory.* The theory and use of these instruments constitute a part of the general course in physics; but the need has long been felt for the proper facilities for applying them in other subjects of study. By an ingenious seating devised by Professor Ordway, the table supporting the instrument is so connected with the dissecting table that the student turns from one to the other without leaving his seat. Each table is supplied with gas and water. The laboratory accommodates ten students at a time, and is a model of convenience and compactness of arrangement. It is in charge of Prof. Ordway, is open to all students in the school requiring this instruction, aud is a valuable and interesting adjunct to our resources.

D. *The Industrial Chemical Laboratory.* For some years the chemical department has felt the urgent need of more room. This has been especially needed in Industrial and Organic Chemistry. The opportunity for providing temporarily for these wants has been offered in the new building. The kettles for dyeing are already set, and the various furnaces and other appliances will soon be in place.

O, P, Q, R. *The Organic Chemical Laboratory* is separated from the remainder of the building by a brick wall and is substantially fire-proof. The benches and hoods are of stone, and the floor of cement. It has been admirably arranged in all its

B. Ice Chamber, 8′ by 5′.

H. Lathe Shop, 37′ by 20′.
I. Chipping and Filing Shop, 32′ 6″ by 20′.

details by Professor Wing, and was built and fitted at his own personal expense, assisted to some extent by a few friends. It will be noticed that the additions to the resources of the chemical department of the Institute, to which I have called your attention, are of a marked and substantial character, and I am happy to say that for breadth, thoroughness, and efficiency in all the details of the instruction we have every reason to be fully satisfied with the present condition of the department.

THE RUSSIAN SYSTEM OF INDUSTRIAL ART EDUCATION.

In the report which I had the honor to make upon this subject soon after my return from Philadelphia in July last, it was seen that the Russian Government had decided some years ago, that in the education of mechanical engineers and machinists, practice should be combined with theory, to the extent that the young engineer should be able to construct his own designs with his own hands. To this end large manufacturing works were connected with the Imperial Technical School of Moscow, which has solicited and executed orders to the amount of thirty-five to forty-six thousand dollars annually. These work were thoroughly organized, with competent engineers at the head of the various departments, with a sufficient number of skilled workmen, and conducted as a commercial establishment. To these large and well appointed works the students were admitted for the purpose of acquiring manual skill and professional practice without any preparation, until 1868. During these years the system of apprenticeship was tested as a part of an educational system under the most favorable conditions. It failed. Unskilled and intermittent labor was found prejudicial to commercial success, while it was also found impossible to develop the manual skill of the students in a systematic and progressive way, with the proper tests for thoroughness and efficiency at every step, with the greatest economy in teaching and supervision to the institution and of time to the student. Since 1868 that system of art teaching has been pursued which

produced the surprising results exhibited at Philadelphia. Here then we have in the experience of this great school, gained through a number of years, a comparison of the two systems; the one of teaching the arts indirectly through their applications in the manufacturing works, and the other of teaching the arts directly as such, and as preliminary and preparatory to admission to these works.

It is indeed true that after the arts have been learned, the next logical step in a full course is to teach their applications through constructions, either in private works, or as is done in the Moscow school. In a government school, when the curriculum covers six years, and the young engineer is needed in the service immediately upon graduation, and has not the opportunity, for any reason, to learn the details of construction in private works, then the attaching of the works to the school may be justified.

I propose now briefly to call your attention to the shops which we have thus far been able to establish, reserving for my next report a full exposition of the system as we have applied it, giving cuts showing the blanks as they come to the student, and also the finished work, with tables of results, showing the percentage of accuracy obtained by each student on every piece of work in each course.

I. *The Vise Shop for teaching the Arts of Chipping, Filing, etc.* In the fitting of this shop I wish to express my great indebtedness to Professor Whitaker, whose practical experience enabled him to judge of the value of the system, and to work out the details of the instruction and supervision which have been so ably and satisfactorily carried out by Mr. Wallburg, who has had the immediate charge of this shop.

The shop contains four heavy benches, each 18 ft. long, 3 ft. wide and $2\frac{1}{2}$ ft. high. To each bench eight vises are attached. It was supposed that one teacher could instruct thirty-two students at a time, and this has been found to be about the right number. At the beginning of the course it is quite enough,

but later, when the students have acquired some skill and independence, a larger number might be successfully taught. As an experiment, we have adopted for this course thirty lessons of four hours each, giving three lessons per week, which is certainly enough for the mechanical engineers, and probably also for the class in the new "School of Mechanic Arts," at first called the new course in Practical Mechanism. At each vise there are four drawers, each large enough to hold all the tools needed by the student at any one time; so that four sections of thirty-two each can take the course simultaneously. This shop has, then, a capacity for teaching the course to 128 students every ten weeks, and to 640 in a year of fifty weeks.

The next step was to devise the proper series of designs to teach the use of the various forms of files and chipping chisels used in any branch of the art, and with a range wide enough to cover all probable applications. At this stage the services of an expert were needed, and we were most fortunate in finding in Mr. Valentine Wallburg, a man who had spent twenty-five years in applying his art skill in various trades, and who had, moreover, the ability to comprehend the unity involved in the details, which he had spent so many years in applying. Each piece is designed to teach a definite idea, and to be put into the course when the student has acquired the requisite skill to work it. As the class system is to be followed, the element of time must be the same for all. The teacher is required to solve each piece in advance of the class, to find the time it will take, having also to settle clearly in his own mind the best method of solution, with the reasons why. At the beginning of a lesson the teacher must be able to assign the time to be given to the class to solve this piece, to show them what it is intended to teach, and to give them the method of solution, with the reasons therefor. These points settled, and all needed directions having been given, all proceed to do the same work, and the teacher's time and energies are all devoted in directing and watching its progress. When the assigned time has expired, all the pieces are called in for inspection, in accordance with an

analysis which has previously been posted, assigning marks to each element for perfect workmanship. These marks add up 100, the same given for perfection in other studies.

The student, by carefully studying the analysis, is able to work, not at a venture, but with knowledge, for the highest marks, and thus his capacity to judge of the quality of work fully keeps pace with his ability to perform it.

We are thus developing the mechanical judgment of the student by making in advance a careful study of the methods of solution, as well as the manual skill to perform, and the ability to judge of the quality of work at the same time. The course in mechanical drawing, which keeps pace with the shop work, and the parallel lecture-room course upon the same art, with its applications in construction, completes the instruction.

That so much skill of hand could be acquired in one hundred and twenty hours' practice has been quite as great a surprise to mechanics as to others, and I am glad to be able to say now from our own experience, and in which I am joined by all with hardly an exception, that the system is a triumphant success.

K. *The Forging Shop.* This shop is fitted with eight forges. The Sturtevant pressure blower, which furnishes the blast for the forges, is placed in the engine room. The hoods over the forges are connected with a 16′ pipe, which runs longitudinally near the ceiling of the shop, and enters a No. 4 Sturtevant exhaust blower just through the partition into room M, and thence through the embankment and foundation of the main building into a flue at its northerly end on Newbury St. This exhaust blower removes completely all smoke and dust, and much of the heat, making this shop one of the best ventilated and most comfortable rooms for work in the Institute.

As the acquiring of manual skill in the art is the principal aim, only such tools are furnished as are necessary to this end, but none of the appliances which are simply used to facilitate work. In establishing this shop it was supposed that two students could work at the same time at each forge, thus giving

sixteen to a section. But in this we have been disappointed. It has been found that considerable skill in the management of the fire, and the use of all the tools, including the sledge, must be gained before two can advantageously be put at the same forge upon two-handed work. On this account the students have had thus far only half the time in the shop that was intended. But even this short time of sixty hours has fully demonstrated the value of the system in teaching this important art, both in the quality and amount of work. You may be interested in a brief statement of the analysis of the art upon which we have based our course of instruction. In the infancy of the art the forger was obliged to operate upon irregular shaped masses of metal and work them into the required form and dimensions. Now the manufacturing works furnish us with iron and steel bars of any given shape and size in cross-section, and with this material the forger has to deal.

Now it is found that the forger's art is substantially included in the six following elements: First, *the management of the fire*, and *degrees of heat*; second, *bending without changing the cross section*; third, *drawing-down*, or reducing the cross section; fourth, *jumping*, or *upsetting*, that is, shortening the piece and increasing its cross section; fifth, *building up*, or *welding*; sixth, *hardening* and *tempering*. Now while the class are studying the forger's art in the class room, under the direction of the professor, either through lectures or some text upon the subject, such as is found in the "Practical Metal Worker's Assistant," by Oliver Byrne, they are at the same time in the shop working out under the direction of an expert a sufficient number of graded examples under each of the above heads to become familiar with the theory, and acquire reasonable skill in the manipulations. I am satisfied that it is of comparatively little use to spend much time upon these subjects without the instruction can be based upon a reasonable amount of practice — but with such a sub-stratum upon which to build, the whole subject becomes permeated with light and life. For instance, it is of little importance for the student to know the fact that

in tempering, certain tints accompany certain approximate temperatures, if he can not have the opportunity of studying these relations by actual practice, and learning at the same time how these facts are related to the uses of the tools he may be called upon to forge and temper.

While it may be true in general that for tempering steel tools for metal working, from 430 to 450 degrees of heat are needed, and that very pale straw yellow indicates about 430 degrees, and a shade of darker yellow about 450 degrees, it becomes especially and doubly true to the student who has once made and successfully tempered such a tool.

I must not close my brief account of this shop without expressing our obligations to Mr. B. F. Sturtevant of this city, who aided in working out the plan of this shop and fitted it at his own expense. He not only came to our aid with his large and successful experience as a skillful manufacturer of just what we needed to make the shop a perfect model of comfort and convenience, when such aid was of the greatest value, but he also expressed his confidence in the method of instruction we had adopted by this generous contribution, with a heartiness and cordiality which entitles him to my lasting gratitude and regard.

We were also fortunate in finding for the teacher of forging, Mr. James Bell, who has devoted forty years of his life to the practice of this art, and who by his skill, zeal and enthusiasm, and thorough comprehension of the system, and faith in its success made it such with every one of the fifty-one pupils who came under his instruction. That we should have found masters of two important arts, Mr. Wallburg and Mr. Bell, both so skillful, and at the same time having an apparently intuitive tact for teaching, is to me a matter of no less surprise than pleasure, and I gladly put on record my personal thanks to both of these gentlemen for the hearty and unfaltering support they have given me in all the details of instruction and discipline.

H. *The Lathe Shop.* In addition to the Vise and Forging Shops already mentioned, it is proposed as fast as the means can be secured, to furnish facilities for teaching the use of machine tools and foundry work, and thus complete the circle of the arts which apply particularly in constructions of iron and steel.

The lathe will be regarded as the fundamental machine tool, and after the student has become familiar with its construction and adjustments, and the tests for precision, he will be required to work out a series of designs, involving as a whole the entire capacity of the tool. All the other machine tools are to be regarded and used as supplementary to the lathe, and the lathe course is to be so designed as to include their use to the extent that experience may render necessary.

L. *The Planer Shop* is to be used for the supplementary tools, and it is thought that the shops H and L will furnish all the space needed for as many tools as one teacher can superintend successfully. American machine tools are now made of such variety and perfection that their skillful use is to be classed high in the scale of metal working arts, and it is only by personal familiarity with these tools that the engineer can ever acquire a tangible and exact knowledge of their capacity and their proper use by those under his direction. It is admitted that to-day there are far too few men in the shops who can use some of the more complicated tools with anything like the requisite skill, and still fewer who are able to adjust and test their accuracy within given limits. It is useless to ask for a degree of accuracy which the tool can not give through faulty construction, or through incompetent handling. The work in these shops is to be made auxiliary to the class room instruction upon the theory and construction of these tools.

M. *The Foundery.* The founder's and the forger's arts are fundamental in all metal constructions. To these we look for the first close approximation to the forms we wish to construct,

and in a complete system of art instruction in metal working, one is quite as important as the other. Nor is there any reason either on the score of space or expense, why the founder's art should be omitted. All the important manipulations in the art can be as well learned in the moulding and casting of a good variety of small forms, as of large ones; the difference consisting mainly in the handling, which usually depends upon special devices, and is not in any sense a part of the art.

When the proposed series of shops are fully equipped, it is easy to see how the instruction in the foundery and the forging shop can be connected with the courses of instruction in the vise and machine tool shops: and especially will the series be complete when we shall have the room and means to establish a pattern shop. Then the student will be able to take his own drawings into the shops and follow them up till the design is brought out in its finished state, either in cast or wrought iron. And further, all this can be done by rigorously following the class system of instruction, applying at each step the most rigorous tests for thoroughness of workmanship. But a comparatively small sum of money is still needed to carry out this plan fully, and I can not but feel that when the importance of this system of art-education is once clearly seen, not only in connection with technical schools, but as supplementing our present public school system, the means will not be wanting to enable us to work out the plan with care in all its details.

You will be pleased to learn that by a recent letter from the Director of the Imperial Technical School of Moscow, I am informed that the Russian Government has authorized him to duplicate the exhibit of that school at Philadelphia for the Institute of Technology.

The Lowell School of Industrial Design. The continued demand for the graduates of this school is the best evidence I can offer of its success. Each year is adding to its efficiency as a school of design; but there is beginning to be a demand made upon it which it has not yet been able to meet. These

young designers can not put their designs upon the loom and exhibit them in the woven fabric, and this art is so closely allied to that of designing that it should be taught in close connection with it.

In foreign schools for teaching the arts employed in the textile manufactures, two phases of the weaver's art are usually kept in view — one that mentioned above, and the other the handling of the loom after the work has been properly mounted. This latter point, I am satisfied from the slight experience we already have, is not important for us to consider. We find that the students have no difficulty in running the loom after a few hours' instruction and experience. In a large manufacturing town I can see that it may be more economical to teach simple weaving in a school, than to be troubled with raw hands in the mills, but for us the question is simply the teaching the student how to make his weaving pattern from the design, and then put it properly upon the loom, and weave enough to show the design in the fabric; and for this purpose hand pattern looms are on many accounts better than power looms. The expense of running power looms is too great simply for pattern weaving, and besides the weaving of a pattern should be done slowly to give the student time to observe the working, and become familiar with the effects of each phase of the design as it appears in the fabric. It is important, however, that the school should be supplied with specimens of several of the more successful power looms of various construction, that they may be used and studied as machines, and some knowledge gained of the adaptability of each for the production of a certain class of goods. The theory and practice of dyeing and sizing come in the Department of Industrial Chemistry. Our wishes in this matter coming to the attention of the Lewiston Machine Co. of Lewiston, Me., we were kindly presented with one of their looms, which has been used for weaving quite a number of designs, and has given great satisfaction to teacher and pupils. We are also indebted to Mr. Edward A. Brigham of Boston, for an English loom, intended for the weaving of plain cotton

cloth and to be run as high as 225 picks per minute; and also to the Bridesburg Manufacturing Co. of Philadelphia, for one of their manufacture; neither of which we have yet had time to set up and use. Other parties have promised to aid us in this way, and we shall have no difficulty in adding this art to our course in designing. Messrs. Mudge, Sawyer & Co. have kindly furnished us with all the yarns needed, from the Washington Mills at Lawrence.

Industrial Science and Art. In what precedes it will be noticed that some prominence is given to the matter of Industrial Art. It has been the spirit of our instruction in all departments to combine theory and practice, that is, science and art, just as far as was practicable in a school. Even in the study of science, the practice, or art side, has been made prominent through our laboratories; and our teaching has been successful almost in the exact proportion to the extent in which we have been able to build the instruction upon a manipulatory, or art basis.

This sort of science teaching is of comparatively modern invention; and this inversion of building the theory upon the practice, or the science upon the art, is only gradually working its way in the teaching of the purely industrial arts through practice shops as a foundation upon which to build, in the mind of the student, a knowledge of the theory or science, which pertains to each, and which is mainly the experience of its practitioners, growing out of all the varying conditions of the applications. As, however, there is a time when science grows out of its corresponding art, so also there is a time when the art grows out of its applications in the trades, or handicrafts; and it becomes a matter of the greatest importance as to which phase of this development we use as the foundation of our industrial education.

In the past, the higher industrial education has been based upon the science phase, and the lower upon the trades, or handicraft, phase. It seems to me that in the future we shall

find it the wisest to build upon the art phase, as the firm and substantial foundation for both the engineer and the artisan, for both the theorist and the practitioner, no matter what the industry may be. Because if the student only acquires the art, he can apply it in the trades as a means of support, while upon the art as a foundation he may build a structure worthy of his highest aspirations.

Conclusion. I am glad to be able to say that the year's work has, upon the whole, been successful. There has been progress in all departments. We have only to regret the want of means to make the work still more successful. Not a single department has the means of meeting its necessary current expenses. In some a small appropriation is made to answer; in too many the minimum needs are made up by the professors; and the necessity for such contributions will last until a larger percentage of our income is derived from invested funds. There is no school or college in the country, so far as I know, whose students' fees constitute anything like such a large percentage of the total income; and I am sorry to know that our fees make it impossible for many young men to join our classes who would otherwise gladly do so. Nor have we the means for aiding needy students possessed by nearly all the older colleges. I refer to these facts here, hoping they may thus come to the attention of those who may be inclined to lend a helping hand.

JOHN D. RUNKLE, *President.*

SECRETARY'S REPORT FOR 1875–1876.

SOCIETY OF ARTS.

There have been held during the year fourteen meetings of the Society of Arts. The first two meetings were devoted to the discussion of the manner in which, if in any, the Society would coöperate with the School of the Institute in the Centennial Exhibition of 1876 at Philadelphia. Though the members consulted were all in favor of such representation, and a committee was appointed to consider the subject, the Society, as such, did not coöperate with the School in its exhibition, which proved of such great advantage to the students and an honor to the Institute — an account of which will be found elsewhere.

SPIRIT COMPASS, ETC.

At the meeting of *Dec. 9, 1875*, Mr. David Baker exhibited and explained the most important features of the so-called "Baker Compass."

The object of his invention was to remedy the defects of spirit compasses, the most prominent of which are: — 1. The liquid with which they are filled is liable to freeze in low temperatures, rendering the instrument useless for the time being. 2. The changing of the paint on the card and interior surface of the bowl from white to dark brown, making it difficult to distinguish the division marks. 3. The inconvenience and expense of taking the card to pieces in order to get at the needles to recharge them when necessary. 4. The leaking or

bursting of a card float at sea, rendering the compass inoperative. 5. The inability of a floating card to turn in the liquid with a desirable degree of activity, in consequence of the friction produced by the float and needle casings. 6. The arrangement and movement of the lubber point.

These defects Mr. Baker claims to have overcome by the following corresponding remedies: — 1. His compass is filled with a thin, transparent kerosene oil which cannot congeal under any temperature to which it is liable to be exposed. 2. His paint is very firm and durable, perfectly imperishable in the oil, and will not scale, crumble, nor wash off; neither will it change to a dark color by the lapse of time. 3. The oil prevents oxidation of the needles and pivot, permitting the construction of a very light card, consisting simply of a sheet of paper with open centre, supported by a thin and narrow rim of metal or other suitable substance, to which the needles are fixed. This permits the direct application of a magnet to the needles, without removing them from the card whenever it is necessary to re-charge them. 4. No float being used or required, the compass can not become inoperative by a card-float leaking or sinking down on one side. 5. The light and thin card, displacing but a small quantity of liquid, and having no weight of casings around the needles and no float to create friction, turns very easily on a steel pivot, maintaining or regaining quickly its position in the magnetic meridian. 6. The lubber point, as usually made, is very deceptive, misrepresenting the direction of the vessel, and has doubtless been the cause of many disasters at sea; it leads the mariner to suppose that he is sailing on a straight line when he is really making a zigzag course; it may appear from this that he is sailing on a particular course, when he is actually sailing some degrees off.

By a simple apparatus attached to his and the old form of compass, he showed that at sea the inaccuracy in the latter was great in proportion to the roughness; when the vessel mounts a wave the bow turns one way off from the course, carrying the lubber line with it; when it descends into the trough of the

sea, it goes rapidly to the other side; so that this line, though indicating the long axis of the vessel, by its swinging motion constantly deceives as to the true course of the vessel; in fact, the experienced helmsman steers more by the direction of the waves and the sails than by the lubber line.

The whole secret is in this: In the old instruments, in every nation, the outer gimbal ring on which the compass swings is suspended on pivots on each *side*, so that any change in the elevation of the bow and stern of a vessel, except in an absolutely vertical plane, must be attended by an oblique motion, which carries the lubber line to one side or the other of the supposed course. He swings his compass on gimbals whose pivots are arranged in the longitudinal instead of the transverse axis of the ship, or *fore and aft*; this deviation of the lubber line thus becomes impossible, and the compass, instead of being an uncertain guide, becomes entirely trustworthy.

EXTINGUISHING OF FIRES ON SHIPBOARD.

Lieut. F. M. Barber, U. S. N., read a paper, illustrated by drawings on the black-board, on extinguishing fires on vessels laden with coal, cotton, or other combustible material. He utilizes the well-known properties of carbonic acid gas in the following way.

In some convenient locality on board, as the spardeck, he places one or more flasks, about three feet long and one foot in diameter, containing about one hundred pounds of the gas in a liquid condition; from the top of the flask runs a small iron pipe, just under the deck, the whole length of the ship; from this, at proper intervals, are branch pipes at right angles, passing to every store room and the hold; any one, or all the cocks, may be turned from the main deck, near the flasks.

On an alarm of fire the hatches are to be battened down, and the gas let on to the compartment where the fire is; the liquid gas, under a heavy pressure, passes in the form of vapor through the pipe, and is instantly driven to the compartment to

which it is admitted; arrived at this point, being one and a half times as heavy as air, it fills the compartment from the bottom upward, without being diluted by the air, producing at the same time intense cold by its expansion, and driving before it through cracks and crevices every particle of air.

The liquid is non-corrosive, and the vapor is not injurious to the most delicate fabrics. It is probably the only substance which will permanently suppress the most advanced stage of combustion in a cargo of coal. One pound of the liquid is equal to over eight cubic feet of gas; it must be contained in vessels capable of sustaining the great pressure.

The objections to its use, viz.: the want of apparatus capable of producing a large quantity in a short time and at a low cost, and of suitable vessels to contain it, have now been removed. He described the apparatus, devised by Mr. W. N. Hill, which produces fifty pounds of liquid gas per hour, at a cost of only fifteen cents a pound. The containing flasks are made of steel, weighing a little over three hundred pounds, and tested to two thousand pounds per square inch, hydraulic pressure; tested to destruction, one gave way at three thousand one hundred and thirty-two pounds per square inch. The flasks are made of sheets of steel, rolled up like curl-papers, one within the other; the outer one is riveted, and all spaces between the sheets are filled with pure tin.

THE LIQUID COMPASS.

December 23. Mr. Edward S. Ritchie read a paper on the "Baker" or "liquid compass," replying to the statements made at the last meeting.

In his compasses he uses alcohol and water, the first of which has never been frozen; the mixture he uses he has never known to freeze when in use on board ship. On examining the "Baker" compass he found the liquid used was naphtha, a highly volatile and combustible liquid, vaporizing and burning at all temperatures. Though this will not affect the paint of

the compass, nor congeal at any temperature to which it is likely to be exposed, it is, he thinks, very objectionable; it is very volatile and difficult to hold, very expansive when heated, requiring a compensation of much greater capacity than alcohol and water, and increasing the danger of bursting the bowl by heat or cold.

Placed as a compass generally is, in a close binnacle, with a lamp lighted inside, if from any cause a leak should occur, a dangerous explosion might result. The changing of the color of the paint is now practically corrected. The magnets are never charged until the cards are ready to be placed in the bowl, and it would be quite practicable to charge them in the bowl. The leaking of a card is possible, but extremely rare, as each one is severely tested under high pressure; his card bears but about forty-five grains on the pivot, while in the new compass it bears with a pressure of half an ounce.

Mr. Ritchie also stated that placing the lubber line in the line of bearing of the gimbal ring was not new, as the ships of the American and English navies had for many years been furnished with compasses whose lines were placed in this position; he had himself made hundreds in this way, and it is by no means certain that this is the best position.

METRIC SYSTEM OF WEIGHTS AND MEASURES.

Mr. Edmund H. Hewins read a paper on the "Metric System," which has been adopted by a majority of nations, including the United States. Standard metres are now deposited at Washington. England is almost the only important government which still withholds its approval.

It is so simple that any person of ordinary intelligence can readily be taught it in a few hours; and no one could pretend to master the old system of apothecary's, avoirdupois, and troy weights, and the inches, feet, yards, fathoms, furlongs, miles, perches, acres, pecks, bushels, gallons, quarts, pints, gills, etc., in many weeks — to say nothing of the general uselessness of the knowledge in any country but his own.

He dwelt on its advantage to mechanics, in enabling them to have a common standard where there is now so much confusion and arbitrary method of measurement, as in screws, taps, dies, etc., both in government and private shops.

Mr. J. P. Putnam continued the subject by reading a communication on the advantages of the system, and the means that had been taken to introduce it into various countries. That decimal division of weights, measures and money, is of the first importance in computation is shown by the praise generally bestowed on the federal currency; and that engineers share in this opinion may be seen by their using decimals of a foot where they can, although, by so doing, they are at variance with the general practice of the community.

The real difficulty is not with the proposed system, but with making the change. The cost of such a revolution, affecting so large a proportion of the transactions of life, must be enormous; but it is equally true, if not quite so obvious, that it is costing enormously to keep up the present confusion. It is already used in the mint and on the coast survey; men of science have used it for many years; it is used by analytical chemists, and will soon be used by many architects and constructors all over the country. To accomplish its introduction concerted action is necessary.

In the metric system, the weight and dimensions of every material thing, — whether solid, liquid, or gaseous, — whether on land or on water, — whether in the earth or in the heavens, — and whether determined by the scale, plummet, balance, barometer, or thermometer, — are ascertained by a method absolutely uniform, entirely simple and equally suitable to the use of all mankind, — resting upon a single invariable standard of linear measure, with multiples and submultiples, like those of our monetary system, — exclusively decimal, with appropriate names, similar in all languages — and itself secure against the possibility of change, or loss through carelessness, or accident, or design, by being constructed on scientific principles, and copied for distribution among the different nations of the

world. The standard unit of length, the metre, is the ten millionth part of the quadrant of the meridian, equal to very nearly 39.37 English inches.

NEW METHODS OF TOPOGRAPHICAL SURVEYING.

January 13, 1876. Prof. E. C. Pickering made a communication on some new methods of topographical surveying among mountains, devised by himself, as distinguished from the old method of trigonometrical survey, which is very expensive as well as inaccurate, and from the plane table, which answers very well for the determination of a few points.

He exhibited a new instrument, with various modifications, for use among the mountains. His object was to dispense with the graduated circle, and its bulky and heavy stand, and to be able to make accurate observations without the necessity of ascending the mountains, thus saving much time, labor and expense. He brought to the notice of the meeting three different methods, each having its special applications.

The first was a new stadium, as a substitute for the one commonly used in the coast survey and elsewhere, which requires the services of two persons, and which is also inaccurate. He uses an ordinary small and portable telescope, lightly but firmly mounted, having a plane glass mirror in front of the object glass; by placing this mirror at the proper angle, the two images of an object are made to coincide. Two positions being taken on the same line, at right angles to the object seen, the measurement of the different angles from these different points enables the observer to measure the distance with a great degree of accuracy.

This instrument, used for measuring horizontal distances, being made to turn 90° on its longitudinal axis, may then be employed for measuring heights. He uses a good level firmly attached to it, and a spider-line micrometer, or eye-piece, containing a divided scale. It is practically, therefore, a zenith telescope, without vertical circle or heavy mounting, but with a

rigid connection between the level and the instrument. Its liability to error is very small, and its use easy and satisfactory.

The third form of apparatus was for working out details, after certain main features had been determined by other means; it was specially valuable for making contour maps, which by ordinary processes are difficult and expensive. His device was a modification of the camera obscura, easily transported and managed. He explained how, by this simple apparatus, the height and velocity of clouds may be determined, the distance of a thunder-cloud, and the velocity of sound.

Attention was drawn to the simplicity and efficacy of these instruments, which would so diminish the cost, and increase the accuracy of topographical surveys, that no State need be deterred from authorizing such survey on the ground of the great expense of the topographical work.

NEW WIND VANE.

January 27. Prof. Pickering described a new form of wind vane, an invention of Mr. W. H. Pickering, now a student at the Institute.

It consisted of an ordinary vane, which had attached to the base of its pivot-socket two arms inclined downwards, one on each side of the vane. To the left hand arm was attached a ball, and to the right a piece of ground glass, of such a size that when viewed from the front it would present the same amount of surface as the ball, both about as large as the letters denoting the points of the compass. The object is to show the direction of the wind under all circumstances, especially when a person in the line of the wind might be unable to tell whether it was north or south, east or west; when the ball appears to the right of the pivot the vane is pointing toward you, and when to the left, away from you. The ball is the object judged by, as the glass would be invisible at a short distance, the use of the last being to counterbalance the weight of the ball and to counteract the action of the wind on it. The improvement is a very cheap one, and can be easily applied to any vane now in use.

INSTRUMENT FOR DRAWING CURVES.

Mr. John M. Batchelder, of Cambridge, sent for exhibition a new instrument, devised by himself, for drawing curved lines, such as are ordinarily made by the French curves.

A diagram of the various and graceful curves which may be drawn by this instrument was exhibited. The opinion was expressed that the flexibility of the steel bands was such that extreme care would be necessary to insure accuracy.

Mr. Moore spoke of the importance of preserving in some way the diagrams made in illustration of the papers read before the Society, in many cases indispensable for the permanent value of communications.

DIFFERENTIAL COMPASS.

February 10. Mr. S. W. Holman, a student of the Institute, in the Department of Physics, presented in behalf of the inventor, Mr. George Iles of Montreal, a new form of mariner's compass, called a "Differential Compass."

The instrument was designed to detect variations of the compass needle, due to the disturbing action of iron ships, and to give the mariner a means of correcting this error at any time, thus obtaining the magnetic north.

After explaining the effect of the iron mass of a vessel on the compass, illustrating the action by magnets, he described the model.

It consists of two compound needles pivoted one above the other. The upper needle is made up of a series of bundles of small steel magnets, held between two long strips of aluminum; the bundles are arranged with their like poles pointing in the same directions, the north pole of one bundle being placed toward the south pole of another. As each small bar magnet can be much more intensely magnetized in proportion to its bulk than a larger one, we can obtain by this arrangement a much more intensely magnetized needle than with an ordinary steel bar. The lower compass needle is an ingenious arrange-

ment of similar small steel magnets across a bar of aluminum, like poles being all upon the same side of the bar. In this way is produced a compound needle, which sets with its length east and west; when pivoted one above the other, the needles set at right angles.

If a piece of soft iron, or an attractive magnetic pole, be introduced into any quadrant near the needles, the quadrant is diminished to an acute angle. Upon this fact is based the method of determination of the deviation of the compass and its compensation. The conclusion of the inventor was that any disturbing mass at any distance would cause the needles to deviate toward each other in some quadrant, forming an acute angle there; this acute angle was to be rendered a right angle again by the repellant pole of a compensating magnet under certain prescribed conditions.

Mr. Holman showed that, from experiments performed by him on this compass in the laboratory, the action of disturbing forces at a distance was not as Mr. Iles had expected,— that an acute angle was produced only when such force was at a small distance from the needle as compared with the length of the small magnets composing these needles,— and that the compass failed to show any variation from a right angle between its needles, when a disturbing magnet had moved them both through a very large angle from a true position.

He then showed, upon theoretical grounds, the reason for these two actions at different distances, making evident in this way the fallacy of the instrument, which had acquired a wide reputation.

NEW SYSTEM OF RIFLING CANNON.

March 9. Prof. E. L. Zalinski, U. S. A., read a paper, illustrated by numerous diagrams and models, on a new system of rifling heavy guns, devised by Mr. S. P. Ruggles, a member of the Society.

The following extracts embrace the principal points in the paper.

He sketched briefly the object of rifling guns, the various

kinds of rifled projectiles, the principal methods in use at the present time, and the arguments of advocates of the uniform and variable pitch or twist of rifling.

The object of rifling guns is to give projectiles, not spherical, a rotary motion, which gives greater range and accuracy, and to impart the maximum projectile force to the shot with the minimum strain upon the gun. These projectiles are known as expansive, compressive, and flanged.

The expansive class are made smaller than the bore to facilitate loading, being used most frequently in the muzzle-loading cannon. The pressure of the powder-gas expands a soft metal cup or base so as to cause it to fill the grooves and rotate the projectile.

The compressive class are made larger than the bore, and used with breech-loaders, and are made to take the rifling by being compressed. They are made of iron or steel, with a thin soft metal coating, usually a compound of lead and tin. This system is gradually being abandoned, as it strains the gun, and reduces the velocity and accuracy.

The flanged class are made with flanges which correspond in position and inclination to the grooves of iron lined on the bearing side with a softer metal. While this class has given good results as to accuracy, range, and penetration, they strain the gun and the flanges are liable to break; they can not be used with a variable twist; they are used, however, by most European nations.

Mr. Ruggles's plan of rifling cannon and projectiles was shown by a model. It contains sixteen grooves of a serrated shape. The grooves used in United States cannon are rectangular, this Mr. Ruggles claims is unnecessary, as only one side of the groove is subjected to any strain or bearing in firing; consequently a number of serrated grooves, each having the same effective bearing surface as the rectangular groove, can be cut in the bore, doubling thereby the bearing surface without weakening the gun.

The projectile has an expansive sabot of soft metal, which is forced into the grooves by the powder gas, which thus gives the

required rotary motion. From this kind of groove the sabot is able to expand, fitting closely the bore at every point, utilizing the entire force of the powder, and preventing the escape of the gas, which is not the case with the service groove. Around the front of the projectile, near the junction of the cylindrical and conical portions, is a soft metal hoop, which is to be expanded by the gas that must pass the base sabot at the first moment of explosion; this will cause it to expand sufficiently to centre the front end, although it may not have fitted the grooves. This band is put on loosely, so that it may turn.

Opinions differ as to the rate and kind of twist that should be given to rifling. There are two kinds of twist used, uniform and varying. The uniform twist is one which imparts the required rotary velocity upon starting the projectile; the increasing variable twist is one which causes the projectile to move straight forward at first, and then gradually acquire its ultimate rotary velocity at the muzzle.

Mr. Ruggles proposes to use an increasing twist, and considers that one based upon the law of gravitation will give the best results. By an ingenious device he has made the twist an exact copy of the law, as to progressive increments of pitch, giving the projectile one revolution in travelling the first 48′ of its flight.

Remarks by several experts in the science of gunnery and projectiles added to the interest of the meeting.

DEVELOPMENTS IN STEAM ENGINEERING.

March 23. Prof. Channing Whitaker read a paper on some "New Developments in Steam Engineering."

De Pambour thought that saturated steam expanding in a cylinder followed the laws of Mariotte and Gay Lussac, that the steam remained saturated during the expansion, and that the weight of steam in the cylinder was constant throughout the expansion; we now know that these ideas are inconsistent with each other.

Mariotte's law is that the pressure is inversely proportionally to the volume; this law he represented by a diagram on the board.

He gave the results of Regnault's, Rankine's, Zeuner's, Fairbairn's, and Tate's experiments, as represented by diagram curves.

After Dr. Joule had determined the mechanical equivalent of heat, it was ascertained that some of the steam in the cylinder would be condensed during expansion if no heat was communicated to it during that time, and hence, it was believed that the expansion line, instead of being a curve of a constant weight of saturated vapor, was a curve of a constantly decreasing weight of vapor. Rankine called this an "adiabatic" curve, and this has been generally accepted by engineers as the one coming nearest to that according to which steam should expand in the cylinder of an engine. It is supposed that the steam neither receives heat from, nor imparts heat to, any other substance during the expansion, but that as much heat as is necessary for the purpose is converted into the work done during expansion. The heat converted into this work is then obtained from the steam which is expanding, and a portion of it is therefore condensed, and the curve is one of a decreasing quantity of saturated vapor.

Prof. Whitaker stated that it is by no means certain that steam in a cylinder should be expected to expand along an adiabatic curve. The supposition that the steam neither receives heat from, nor imparts heat to, any other substance during expansion, is an untenable one, and the conclusion is in error to the extent that it is affected by this supposition. He laid before the meeting some facts which led him to believe that the conditions of ordinary expansion are not those of the adiabatic curve.

In almost all cases, indicator diagrams taken from unjacketed engines using saturated steam expansively, show a greater increase in the weight of steam during expansion than if the steam had expanded along a Mariotte's curve. During the winter of 1874–75 many experiments were made by the students in the Mechanical Engineering Laboratory of the Institute bearing upon the question of condensation and re-evaporation in the cylinder. He gave an abstract of the thesis of Mr.

J. H. Head, from which it appeared that in unjacketed cylinders the co-efficient of expansion of saturated steam, established theoretically by Rankine as $\frac{1}{0}$, is incorrect in ordinary practical usage; the co-efficient is not constant, varying in different engines, and even at different cut-offs in the same engine.

Two principal reasons have been assigned for the increase in the weight of steam in the cylinder during expansion: — leakage, and re-evaporation of water which entered as steam and condensed against its cool walls during the early part of the stroke, the re-evaporation being produced by heat returned to the steam during expansion by the walls of the cylinder. As to the first, it seemed to him reasonable to suppose that in most cases at least as much steam will leak out of as into the cylinder during the expansion. He thinks the results more likely due to condensation and re-evaporation.

BLOOD GLOBULES OF MAN AND MAMMALIA COMPARED.

April 6. Dr. Ephraim Cutter exhibited micro-photographs of the blood of man and of some of the mammalia, taken by himself.

The object of his researches was to ascertain what ground, if any, medico-legal experts had for saying that they could distinguish the blood of a child from that of an adult, or that of man from that of any other mammal.

The images thrown on a screen by the calcium light can be measured directly, and any observer can decide for himself whether such discrimination is possible, as size is the only morphological element of the red blood corpuscle taken into account by such experts.

The averages of the measurements were as follows:

Man	1-3100	to 1-8200	of an inch.
Dog	1-3200	" "	"
Squirrel	1-3600	" "	"
Rat and Rabbit	1-3400	" "	"
Deer	1-3500	" "	"
Ox	1-3900	" "	"
Pig	1-4028	" "	"
Horse	1-4200	" "	"
Sheep	1-5600	" "	"

All were taken with the same $\frac{1}{50}$ objective of Tolles at a distance of 26 inches, and reduced upon the glass positives at the same distance from the camera. The powers used are very much higher than have ever before been employed in microphotography.

Whether such small differences could be of any value in legal medicine, especially as in the same specimen the size varies considerably, he left for others to determine.

He also exhibited the appearances presented by diseased blood, in the various stages of consumption, showing characteristic changes in the outlines, appearance, and contents of the globules.

Dr. Cutter exhibited an invalid chair of his invention, in which all the parts have an independent motion in a vertical plane, corresponding to the movements of the natural divisions of the body.

Mr. H. P. Langley read a paper on windmills, and some of the wasted forces of nature. He described a cheap machine of his invention, useful for pumping and other domestic purposes.

ELECTRIC RAILWAY SIGNALLING.

April 27. Mr. William Robinson read a paper on his system of "Wireless Electric Railway Signalling, and the prolongation of batteries" — illustrated by a working model.

His invention shows that the intricate and expensive system of line wires is unnecessary, and that excellent conductors are found in the ordinary rails of the track, resting on the ties in the usual manner and without insulation, disproving the generally received opinion that the electric current would be speedily lost by passing to the earth, especially in wet weather, unless perfect insulation is secured. He gave a sketch of the various attempts to use the rails as conductors, from an English patent in 1848, to his own invention, which would hardly be intelligible without the diagrams.

He also read a paper on his new method of prolonging the

duration of batteries, and gave what he believed to be the explanation of the facts.

MINING LABORATORY OF THE INSTITUTE.

Prof. Richards read a paper on the Mining Laboratory of the Institute, comparing its present with its former condition. In the improvements introduced, the idea has been constantly in mind that the Institute requires real machines, and not toys, to work on a small scale; he believes that any ore susceptible of washing can be practically treated in this laboratory. It connects the school practically with the mining interests of the country, by sending out students capable of putting into successful operation machines they are familiar with. It protects the public from imposition, and private individuals from delusive hopes of a fortune, by establishing a criterion of just and true treatment by disinterested and able experimenters. The future is full of promise.

EXPERIMENTS ON SOUND.

May 11. Mr. William W. Jacques, a student in the Physical Department of the Institute, read a paper, illustrated by diagrams and apparatus, on some new experiments on Sound made by himself.

They consisted of three series: the first was made for the purpose of testing the law of inverse squares; the second to show that the principles of Fresnel and Huyghens, announced for the ether waves, could be applied to waves of sound; and the third, for the purpose of measuring the velocity of sounds of considerable intensity.

There is every dynamical reason for believing that the intensities of light, heat, and sound diminish as the reciprocals of the squares of the distances from their origins. That this is true of light and heat has been demonstrated experimentally; his experiments proved that this law applies also to sound, the observed and calculated results agreeing almost exactly.

There seems to be no *a priori* reason why the principles of Fresnel and Huyghens should not be applied to our atmosphere, and the experiments of Mr. Jacques on the diffraction of sound show that they may be so applied. From his data we may calculate the length of a sound wave, the velocity of sound, and, in short, all of the quantities dependent upon the velocity of sound as well as acoustic quantities analogous to the optical quantities deduced from the diffraction of light.

Many eminent mathematicians and physicists have raised questions as to whether the velocity of sound is not affected by its intensity and pitch, by barometric pressure, hygrometric state, and by other supposed causes. Mr. Jacques's experiments had for their object the measurement of the velocity of sound near the mouth of a cannon. His method consisted of an automatic measurement of the velocity between the members of a series of membranes, placed at different distances from the source of sound, by causing the sound, as it passed each membrane, to register its passage, by means of suitable electric connections, on a chronograph. The experiments were carried on at Watertown arsenal by means of a six-pound cannon. He carefully described the manner of conducting the experiments, which showed that the velocity of sound in the vicinity of a gun is greater than at a distance, by several feet. This is in accordance with theory. The method, when perfected, will probably furnish the most accurate results of the velocity of sound yet obtained.

NEW FORM OF PLANE TABLE.

Prof. Pickering exhibited a simple and inexpensive form of plane table. He called attention to the gradual change in the instruments used by surveyors, the plane table gradually taking the place of the compass. The principal obstacle to its general use is its expense, which, as ordinarily made, is not less than that of a transit, amounting sometimes to nearly three hundred dollars. Its weight, also, is so great as to render its use diffi-

cult among the mountains, and the accurate fitting of some of the parts renders them very liable to injury.

He described and exhibited his instrument, which can be furnished for the sum of fifteen dollars. The cost of the proposed surveys of this and other States may be materially reduced, since the expense of the topography is generally a serious difficulty, and this could be very much lessened if large numbers of competent observers, like the Institute classes, could be provided with inexpensive instruments.

TELEGRAPHING MUSICAL SOUNDS.

May 25. Prof. A. Graham Bell read a paper, illustrated by several experiments, on "telephony" or the telegraphing of musical sounds.

It has long been known that an electro-magnet gives forth a sound when it is suddenly magnetized or demagnetized. When rapidly produced the effect upon the ear is that of a musical note. The discovery of galvanic music by Page in 1837 led inquirers in different parts of the world, almost simultaneously, into telephonic research.

As his researches will be published in full elsewhere, a brief abstract only of some of the principal points will be given here. [Proc. Amer. Acad. of Arts and Sciences. Vol. XII.

In the autumn of 1874, Prof. Bell discovered that the sounds emitted by an electro-magnet under the influence of a discontinuous current of electricity are not due wholly to sudden changes in the magnetic condition of the iron core (as heretofore supposed), but that a portion of the effect results from vibrations in the insulated copper-wires composing the coils. An electro-magnet was arranged upon circuit with an instrument for interrupting the current, — the rheotome being placed in a distant room, so as to avoid interference with the experiment. Upon applying the ear to the magnet, a musical note was clearly perceived, and the sound persisted after the iron core had been removed. It was then much feebler in intensity,

but was otherwise unchanged, — the curious crackling noise accompanying the sound being well marked.

The effect may probably be explained by the attraction of the coils of the wire for one another during the passage of the galvanic current, and the sudden cessation of such attraction when the current is interrupted.

Very striking audible effects can be produced upon a short circuit by means of two Grove elements.

Loud sounds are emitted by pieces of iron and steel when subjected to the attraction of an electro-magnet which is placed in circuit with a rheotome. Under such circumstances, the armatures of Morse-sounders and Relays produce sonorous effects. He has succeeded in rendering the sounds audible to large audiences by interposing a tense membrane between the electro-magnet and its armature. The armature in this case consisted of a piece of clock-spring glued to the membrane. The instrument was connected with a parlor organ, the reeds of which were so arranged as to open and close the circuit during their vibration. When the organ was played the music was loudly reproduced by the telephonic receiver in a distant room. When chords were played upon the organ, the various notes composing the chords were emitted simultaneously by the armature of the receiver.

The simultaneous production of musical notes of different pitch by the electric current, was foreseen by him as early as 1870, and demonstrated during the year 1873. Elisha Gray, of Chicago, and Paul La Cour, of Copenhagen, lay claim to the same discovery. The fact that sounds of different pitch can be simultaneously produced upon any part of a telegraphic circuit is of great practical importance; for the duration of a musical note can be made to signify the dot or dash of the Morse alphabet, and thus a number of telegraphic messages may be sent simultaneously over the same wire without confusion by making signals of a definite pitch for each message.

If the armature of an electro-magnet has a definite rate of oscillation of its own, it is thrown bodily into vibration when the

interruptions of the current are timed to its movements. For instance, present an electro-magnet to the string of a piano, it will be found that the string which is in unison with the rheotome included in the circuit will be thrown into vibration by the attraction of the magnet.

All the effects noted above result from rapid interruption of a voltaic current, but sounds may be produced electrically in many other ways.

The Canon Gottoin de Coma, in 1785, observed that noises were emitted by iron rods placed in the open air during certain electrical conditions of the atmosphere; Beatson produced a sound from an iron wire by the discharge of a Leyden jar; Gore obtained loud musical notes from mercury, accompanied by singularly beautiful crispations of the surface during the course of experiments in electrolysis; and Page produced musical tones from Trevelyan's bars by the action of the galvanic current.

When an intermittent current is passed through the thick wires of a Ruhmkorff's coil, very curious audible effects are produced by the circuit.

When a voltaic battery is common to two closed circuits, the current is divided between them. If one of the circuits is rapidly opened and closed, a pulsatory action of the current is occasioned upon the other. All the audible effects resulting from the passage of an intermittent current can also be produced, though in less degree, by means of a pulsatory current.

When a permanent magnet is caused to vibrate in front of the pole of an electro-magnet, an undulatory or oscillatory current of electricity is induced in the coils of the electro-magnet, and sounds proceed from the armatures of other electro-magnets placed upon the circuit.

The effect was much increased when a battery was included in the circuit. In this case, the vibration of the permanent magnet threw the battery-current into waves. A similar effect was produced by the vibration of an unmagnetized tuning-fork in front of the electro-magnet. The vibration of a soft iron

armature, or of a small piece of steel spring no larger than the pole of the electro-magnet in front of which it was placed, sufficed to produce audible effects in the distant room.

Electrical undulations can be produced directly in the voltaic current by vibrating the conducting wire in a liquid of high resistance included in the circuit, as water, dilute sulphuric acid, or saturated solution of salt.

Sullivan discovered that a current of electricity is generated by the vibration of a wire composed partly of one metal and partly of another; and it is probable that electrical undulations were caused by the vibration. The current was produced so long as the wire emitted a musical note, but stopped immediately upon the cessation of the sound.

Although sounds proceed from the armatures of electro-magnets under the influence of undulatory currents of electricity, he has been unable to detect any audible effects due to the electro-magnets themselves.

The telephonic effects described above are produced by three distinct varieties of currents, which he terms respectively intermittent, pulsatory, and undulatory. Intermittent currents are characterized by the alternate presence and absence of electricity upon the circuit; pulsatory currents result from sudden or instantaneous changes in the intensity of a continuous current; and undulatory currents are produced by gradual changes in the intensity of a current analogous to the changes in the density of air occasioned by simple pendulous vibrations.

The experiments were novel and successful, and were witnessed by a large audience.

The meetings were then suspended for the season.

Mr. George W. Hammatt was elected an Associate Member. Messrs. A. T. Hall, George W. Pratt, and Thomas W. Pratt, have died during the year. Eight members have resigned, and four have been dropped for non-payment of fees. The list now comprises 63 life and 185 associate members.

SCHOOL OF INDUSTRIAL SCIENCE.

The attendance at the School of Industrial Science for the year has been 299, as follows: Resident graduates, 11; Regular students of 4th year, 43; of 3d, 43; of 2d, 30; of 1st, 66;—Students not candidates for a Degreee: 4th year, 15; 3d year, 14; 2d year, 21; 1st year, 19; Architectural Students, 23; Students in Practical Design, 25, of whom 12 were females—total 299, of whom 8 were graduates of other Institutions. Of these about two-thirds were from Massachusetts, principally from Boston and its vicinity; — from other New England States, 22; viz.: from Maine, 6; New Hampshire, 6; Connecticut, 5; Rhode Island, 4; Vermont, 1. From other States, there were from New York, 9; Ohio, 8; Illinois, 7; Indiana, 3; Pennsylvania, Iowa, Kentucky, Minnesota, California, 2 each; New Jersey, Michigan, Virginia, and District of Columbia, one each; from Japan, 4; from the Hawaiian Islands, Canada, and New Brunswick, one each.

Thirty-four professors and teachers have been connected with the school, and several advanced students have rendered assistance in the various laboratories and in surveying. The fees rom students have amounted to about $46,000.

The class in the School of Design has been full, and the work has been entirely satisfactory.

The Lowell Free Courses for the year were as follows:

I. *General Chemistry.* Twenty-four laboratory exercises, of two hours each, on Wednesday and Saturday afternoons, at 2½ o'clock, by Professor Nichols, beginning Nov. 3.

II. *Qualitative Analysis.* Twenty-four laboratory exercises, of two hours each, on Wednesday and Saturday afternoons, at 2½ o'clock, by Professor Nichols, beginning Nov. 3.

III. *Philosophy.* Eighteen lectures for beginners, on *Kant's Critique of Pure Reason*, on Monday and Wednesday evenings, at 7½ o'clock, by Professor Howison, beginning Nov. 8.

IV. *Physiology and the Laws of Health.* Eighteen lectures on Tuesday and Friday evenings, at 7½ o'clock, by Professor Kneeland, beginning Nov. 9.

V. *Heat and its Applications.* Eighteen lectures on Tuesday and Friday evenings, at 7½ o'clock, by Professor Ordway, beginning Nov. 9.

VI. *Perspective and the Perspective of Shadows, with Applications.* Eighteen lessons on Wednesday evenings, at 7½ o'clock, by Professor Ware, beginning Nov. 3.

VII. *Light in its Relation to Color.* Eighteen lectures on Wednesday and Saturday afternoons, at 3 o'clock, by Professor Cross, beginning Jan. 12, 1876.

VIII. *Elementary German.* Eighteen lessons on Monday and Wednesday evenings, at 7½ o'clock, by Professor Otis, beginning Nov. 22.

These were open to both sexes over eighteen years of age; applicants to apply in their own hand-writing, stating age, occupation, and previous preparation. These courses are always well attended by persons desirous of substantial teaching, and having a serious purpose of improvement.

MEETINGS OF THE CORPORATION.

The Corporation has held nine meetings during the year.

At the meeting of Oct. 18, 1875, it was voted to establish a dining room for the students in the gymnasium building.

At the meeting of May 10, 1876, it was voted that the Committee on the School be authorized to cause a laboratory to be constructed for advanced instruction in Chemistry and allied subjects to women, provided that the funds are contributed by the "Women's Educational Association."

At the same meeting the Committee were authorized to open such departments of the school as they see fit, to advanced special students of either sex, or to special classes, where it can be done without interfering with the regular work of the school—on payment of certain fees.

At the meeting of June 7th, it was voted to confer the Degree of Bachelor of Science on the following students who had complied with all the requirements therefor:

Thos. Aspinwall, Jr.	Brookline	Civil Engineering.
T. W. Baldwin, A. B.	Bangor, Me.	" "
Joshua B. F. Breed	Louisville, Ky.	" "
Harry T. Buttolph	Buffalo, N. Y.	" "
Fred. K. Copeland	Winchester	" "
John R. Freeman	Lawrence	" "
Frank W. Hodgdon	Arlington	" "
Arthur L. Mills	Everett	" "
Henry Raeder, Jr.	Hyde Park	" "
Henry M. Waitt	Nantucket	" "
Henry B. Wood	Woburn	" "
Charles L. Rich	Morrisville, Vt.	" "
Wm. P. Jewett (72-3)	Cape Elizabeth, Me.	" "
Henry L. Ripley (72-3)	Kingston	" "
Aaron D. Blodgett	Boston	Mechan. "
Clarence L. Dennett	Beverly	" "
Francis E. Galloupe	Lynn	" "
Sumner Hollingsworth	S. Braintree	" "
Alfred C. Kilham	Beverly	" "
Theodore J. Lewis	Philadelphia, Pa.	" "
Chas. T. Main	Marblehead	" "
Chas. F. Prichard	"	" "
Chas. F. Allen	Cincinnati, O.	Mining "
Alfred E. Hunt	Hyde Park	" "
Sam'l James, Jr.	Cambridgeport	" "
Thos. W. Robinson	Chicago.	" "
Theo. E. Schwarz	Boston	" "
Julius H. Susman	"	" "
Walter D. Townsend	"	" "
Wm. P. Atwood	Lowell	Chemistry.
Chas. R. Fletcher	Chelsea	"
Albert H. Low	Boston	"
Chas. N. Waite	Medford	"
Wm. E. Nickerson	N. Somerville	"
Robert H. Gould	E. Cambridge	Metallurgy.
Walter B. Barrows	Reading	Natural History.
Wm. O. Crosby	Washington, D. C.	" "
John B. Henck, Jr.	Boston	Physics.
Silas W. Holman	Framingham	"
Wm. W. Jacques	Newburyport	"
Willis E. Davis	San Francisco, Cal.	Science and Literat'e.
Chas. A. Sawyer	Chicago, Ill.	" " "

David W. Phipps . . . Boston . . . . . Philosophy.
Robert C. Ware, S. B. . Marblehead . . . . "

The subjects of the Theses, and the abstracts of the same, will be found in subsequent pages.

The progress of the School in the various departments will be found in the reports of the President and Professors.

At the meeting of Aug. 17th, it was voted to approve the plan for the new course in Practical Mechanism proposed by the President, and to construct a one story brick building for that and advanced and organic chemistry, the funds having been contributed by the Charitable Mechanic Association, the Women's Educational Association, and from sources unconnected with the funds of the Institute.

SAMUEL KNEELAND, *Secretary.*

Boston, Oct. 2, 1876.

DEPARTMENT OF PHYSICS.

BOSTON, JAN. 31, 1877.

Prof. J. D. RUNKLE,
President of the Mass. Inst. of Technology.

DEAR SIR:—

My official connection with the Massachusetts Institute of Technology, which has extended over a period of precisely ten years, terminates to-day. I therefore take this opportunity of presenting a statement of the work I have accomplished, and of comparing the condition of the Physical Department and the nature of the instruction with that of ten years ago. At that time instruction in Physics was universally given by lectures and recitations illustrated by experiments and diagrams. A student wishing to pursue this subject further, might aid his instructor in preparing these experiments, and thus become qualified in his turn to deliver the lectures. The first step towards the introduction of a new order of things seems to have been taken by Prof. Wm. B. Rogers, then President of the Institute, and Professor of Physics and Geology. In a pamphlet entitled "Scope and Plan of the School of Industrial Science of the Massachusetts Institute of Technology," published in 1864, the following paragraph headed "Practice in Physical and Chemical Manipulations" occurs on page 23:—

"It will be the object of these exercises to make the student practically familiar with the adjustments and use of the apparatus and agents employed in the more important experiments and processes in natural philosophy and chemistry. With this view, the students, under the direction of their teacher, will be called, by small classes at a time, to execute with their own hands various experiments in mechanics, pneumatics, sound, optics, electricity, and other branches of experimental physics, and to exhibit chemical reac-

tions, to fit up chemical apparatus, to prepare gases and other products, and demonstrate their properties by suitable experiments, accompanying these manipulations, when required, with an explanation of the apparatus used, or of the process or experiment performed."

On page 24 the following paragraph occurs under the heading "Laboratory of Physics and Mechanics": —

"In this laboratory, it is proposed to provide implements and apparatus with which the student may be exercised in a variety of mechanical and physical processes and experiments. Thus he may learn practically the methods of estimating motors and machines by the dynamometer, of experimenting on the flow of water and air, or other gases, and of testing the strength of the materials used in construction. He may become familiar with the adjustments and applications of the microscope; be practised in observing with the barometer, thermometer and hygrometer; and, in a room fitted up for photometry, may learn the mode of measuring the light produced by gas and other sources of illumination, and the value of different kinds of burners, lamps, and their appendages."

This appears to be the first clear statement of the desirability of teaching Physics by the Laboratory method, but owing to the pressure of other business and the lack of means, the matter stopped at this point, and no definite plan was formed for carrying it out.

Accordingly the first instruction in Physics at the Institute was given by the usual illustrated lectures, and this continued to be the case for the two following years. Meanwhile, my appointment in charge of the exercises in Physics led me to consider whether a plan for a Physical Laboratory might not be developed, and, accordingly, in April, 1869, a scheme was offered to the Government of the Institute and printed and distributed among them, under the title "Plan of the Physical Laboratory."

This plan was carried out the following autumn, and has been in operation ever since without sensible change, except in extending its scope. In fact, out of sixteen experiments published in 1870 all but one or two are still in use without alteration.

The cost of establishing this Laboratory was exceedingly small. The argument used was, "this is an experiment and may not prove a success, therefore we will begin on a small scale, and if it accomplishes its end the public will at once appreciate its value, and it will not be difficult to obtain a liberal support, while if unsuccess-

ful, the loss to the Institute will be small." Here, if anywhere, the mistake was made; it accomplished far more than its projectors anticipated, but the public, seeing how much had been accomplished with so little, supposed that no more was needed. The great need of the Physical Laboratory at the present time is an independent endowment, by which, as regards apparatus, it may be placed on an equal footing with other Laboratories since established. Instead of an original expenditure of several thousand dollars, the cost to the Institute was little beyond that of fitting up the room adjoining the lecture-room with tables, and gas and water fixtures, and most of this was done by those already connected with the Institute. The apparatus was largely constructed in a similar manner, at small cost, and without regard to looks, the working being almost the sole consideration. Notwithstanding these adverse circumstances, the work of the Laboratory has been continually increasing. The space first provided proving insufficient, a portion of the long room at the end of the building was added, and soon after the whole of this room was appropriated to this purpose. Two large rooms, one nearly a hundred feet in length, were thus devoted to Laboratory work. But, as many small rooms were needed rather than a few of large size, two alcoves were partitioned off from the main room, one devoted to a chemical store-room, and the other fitted with tools for a workshop. Recently, a partition has been run along one side of the large room, by which small rooms are formed for electrical measurements, photometry and optical experiments requiring the exclusion of a portion of the light. The use of a portion of the closet adjoining the physical lecture-room has also been granted for a battery room, and for photographic work, and last year the room to the east of the front door has been darkened, so that it may be used for spectroscopic and other similar work. Notwithstanding this large amount of space, it is not of the kind best adapted to a Physical Laboratory. Accordingly last summer I presented a plan by which the same facilities could be obtained with a much more economical arrangement of space. I proposed that the present rooms should be given up to lecture-rooms, or some of the other purposes to which they are admirably adapted, and that a block of three small dwelling houses should be con-

verted into a Physical Laboratory. One of these could be leased to the Director, and the other two would contain the large number of small rooms especially required for this work. Among the numerous advantages of this plan are the economy, considering the additional space gained, the means of erecting stone piers to secure steadiness for delicate instruments, the light for spectroscopic and photographic work, the easy access to the ground for out-door experiments, the comparatively unobstructed view for astronomical or meteorological observations, and the convenience for undertaking experiments requiring power.

The work of the Laboratory may be divided into three classes: that for the regular students, additional courses, and original investigation. The first of these has been fully described elsewhere, in previous reports, in the Catalogues of the Institute, and in the "Elements of Physical Manipulation." The latter work, in particular, gives in detail the work of the Laboratory, and is, in fact, based on the manuscript directions to students in performing their various experiments. It will therefore be sufficient here to state, in a general way, what would be the work of an average student in the third year in the course as now given. The actual experiments differ a little in each case, but the following list shows approximately what is done by every regular student in the third year's Class.

3. *Insertion of Cross-Hairs*, teaching the student to handle delicate objects.

11. *Calibration of Water*, for graduating vessels.

12. *Cathetometer*, measuring the height of columns of liquid.

14. *Spherometer*, measuring the curvature of a lens.

15. *Estimating tenths of a Second*, as in very accurate measurements of time.

23. *Composition of Forces*, illustrating the parallelogram of forces.

25. *Parallel Forces*, measuring their resultant and comparing with theory.

28. *Crank motion*, comparing the relative positions of a piston rod and fly-wheel with that given by theory.

35. *Deflection of Beams*, proving the laws of elasticity.

41. ***Borda's Pendulum***, determining the force of gravity by the time of vibration of a pendulum, and measuring its length by (20) ***Reading Microscopes***.

45. ***Hydrometers***, showing how specific gravity is found.

46. ***Specific Gravity Bottle***, for measuring specific gravities.

67. ***Absorption Photometer***, measuring the light cut off by glass.

69. ***Bunsen Photometer***, for testing the quality of illuminating gas.

76. ***Spectroscope***, observing and measuring various spectra and analyzing by the spectroscope various unknown mixtures.

78. ***Law of Lenses***, comparing their observed and computed foci.

79. ***Microscope***, using various appliances, as reflected and oblique illumination, camera lucida, micrometers, etc.

88. ***Opthalmoscope***, viewing the interior of an artificial eye, illustrating various diseases.

92. ***Polarized Light***, illustrating a subject otherwise acquired by the student only with difficulty.

96. ***Telegraph***, teaching the student to send messages.

98. ***Law of Galvanometer***, or currents corresponding to various deflections.

102. ***Wheatstone's Bridge***, measuring resistances with apparatus like that used on the Atlantic Cable.

103. ***Resistance Coils***, making and testing resistances by the British Association Bridge.

105. ***Electromotive Force and Resistance of a Battery***, or a complete test of a galvanic battery.

118. ***Force of Magnets***, or their attraction measured at various distances.

125. ***Expansion of Liquids***, with various temperatures.

132. ***Law of Cooling***, or the connection between time and temperature.

133. ***Pressure of Steam***, at various temperatures.

138. ***Specific Heat***, measuring first that of water.

145. ***Efficiency of Gas Burners***, measuring the number of units of heat generated with a given burner per cubic foot of gas burned.

Since this only represents about fifty hours' work, or two hours a week for twenty-five weeks, the apprehension that all the time would be spent on a few experiments, proved groundless. If the means were sufficient to keep the apparatus in perfect order, there is no reason that this amount of work should not be made the minimum required of all students. Several of the more advanced institutions of learning in this country have already successfully adopted our system in the form in which we use it, and at many others its adoption is strongly desired. The only other plan competing with it, is that in which every experiment shall be very exhaustively treated, which requires a long time to be devoted to each one. This system may have advantages for specialists (though even then I think it should follow that given above), but I doubt its advisability with large classes of students not particularly interested in physics as a profession. As a matter of general culture, the list of experiments detailed above would have greater value than any single experiment, however fully treated. The use of the course here described as a means of culture should not be overlooked, as it is with this object that its introduction into our larger colleges is to be expected. A student accustomed to learn merely from books acquires a new knowledge of physical phenomena, when he himself proves the correctness of theoretical laws by actual experiment. Facts thus learned are also far more readily remembered. An interesting feature of this method of teaching is the rapid improvement, especially with classes who have had no previous laboratory practice. Such a class, during their first hour, accomplish almost nothing, and almost discourage both themselves and their instructor; the next hour shows an improvement, and before many weeks, experiments are readily performed without question, which at first were quite unintelligible to them.

A good test of the character of the instruction, is the relation of teacher to pupil. My own relations, which have always been of the pleasantest character, I ascribe largely to the interest of the classes in their work. They remain beyond the hour, encroach upon their dinner-hour, and frequently ask, and are allowed, to work at other times which they might devote to amusement. With this condition of things disorder is almost unknown, and

they are treated, and I believe regard themselves, as friends and guests, rather than as pupils. Of course the consequence shows itself in a largely increased amount of work, and a saving of much of the nervous wear and tear of a teacher's life.

These remarks apply with still more force to the work of the fourth year, which is largely of a professional nature. The students in Civil Engineering and Architecture devote two hours a week to work in the Physical Laboratory for half of their fourth year. The work during the present year serves as a type of that previously done. This year two students planned and built a truss of a form suitable for a roof, and measured its change of shape under various loads. It finally broke under three hundred pounds, while the bars of which it was formed would not have borne a tenth part of the weight. Others studied the laws of continuous girders, and compared the deflections with those given by theory; others tested a water-motor, measuring the flow, the pressure, the work done, the speed and other elements, and from these computed the efficiency. Others, again, measured the strength of wires, the force required to strip a nut off a bolt, and compared the effect of impact, as in a pile-driver, with a dead weight. In former years, several excellent models of bridges have been built by students, and these are now used for tests of change of form with varying loads and for other purposes.

Several other courses have also been given, mostly to students intending to make Physics their profession. Of these the following may be mentioned:—

Mechanical Engineering. Formerly the mechanical engineers spent four hours a week in their fourth year in the Laboratory. With the establishment of a Mechanical Laboratory this work has been given up, and the course is now given to the students in Physics only. It includes various mechanical measurements, as flow of water, strength of materials, velocity of shafting, friction and power (Phys. Manip., II, pp. 109–138).

Lantern Projections. To students in Physics only. The various methods of using the lantern as a means of instruction (Phys. Manip., II, pp. 212–253). Last year, when several students in the fourth year were devoting themselves to Physics, this course was supplemented by some exercises which proved most successful

and useful. Some lectures were given by these students to pupils of some of the neighboring private schools, and illustrated by the lantern and the other lecture apparatus of the department. Thus our students acquired the very best experience to fit them as teachers. The course in Lantern Projections has sometimes been given by Prof. Cross, in connection with his own lectures.

Geodesy. Last year, finding that the students in Civil Engineering received little instruction in this branch of higher surveying, a course of lectures was given to the older students on geodesy and topography, with especial reference to the Geological Surveys now under consideration in many of the United States.

Practical Astronomy. This course, which has been given for the last two years in the form of lectures, promises, by its adoption, an excellent opportunity to some college, provided with the necessary instruments, for the establishment of an Astronomical Laboratory (Physical Manip., II, pp. 166–212).

Photography. This course, originally given by Mr. Whipple, is now given by Prof. Cross to students in Physics only.

Advanced Physics. One of the most successful courses for the special students in Physics is that bearing this name. The form of each exercise is that of a scientific meeting, different students being selected in turn as secretaries. The advantages of a student's society are attained, while the objections of irregular attendance, and that the work would fall mainly on two or three members, are obviated by requiring from all, attendance and the presentation of papers. Each student in turn presents papers, often illustrated by experiments, either on some original work, or a review of some recently published research, or of the latest scientific periodicals. Many of the standard researches in physics have been thus presented, and other matters of value to every scientific man, such as the character of various scientific societies and periodicals and other similar matters. This, with the lectures referred to above, qualifies each student to express himself clearly and composedly before an audience.

For the past two years instruction has been given in the Physical Laboratory to the students of the Boston University, with results highly satisfactory to us. The laboratory course has thus been successfully tested with a class whose previous preparation

has been literary rather than scientific. The income derived could, moreover, have ill been spared in maintaining the Laboratory.

The great object to which my work for these last ten years has been directed, has been original investigation. This is the real goal to which the attention of a student in the Physical Laboratory is directed. The value of the course in physical manipulations is largely that it teaches a student to think for himself, and prepares him with methods by which he may solve any problem for himself experimentally. I have endeavored to impress on all our students in physics the principle that original investigation should be the great aim of every scientific man. In consequence, a great deal has been done in the laboratory that is new, but in many cases there has been neither time nor means for publication. The following articles have been published under the titles here given. Where I have aided the student largely in the work, my name appears; in the other cases the work has been done almost entirely by the student.

* On the Focal Length of Microscope Objectives. By Chas. R. Cross. *Journ. Frank. Inst.*, lix, 401 (June, 1870).

On the Relative Efficiency of Kerosene Burners. By Chas. J. H. Woodbury. *Journ. Frank. Inst.*, xcvi, 115 (Aug., 1873).

The Phonautograph. By Chas. A. Morey. *Amer. Journ. Sci.*, cviii, 130 (Aug., 1874).

I. Foci of Lenses placed obliquely. By Prof. E. C. Pickering and Dr. Chas. H. Williams. *Proc. Amer. Acad.*, x, 300.

II. Light transmitted by one or more Plates of Glass. By W. W. Jacques. *Proc. Amer. Acad.*, x, 389.

III. Intensity of Twilight. By Chas. H. Williams. *Proc. Amer. Acad.*, x, 421.

IV. Light of the Sky. By W. O. Crosby. *Proc. Amer. Acad.*, x, 425.

V. Light absorbed by the Atmosphere of the Sun. By E. C. Pickering and D. P. Strange. *Proc. Amer. Acad.*, x, 428.

VI. Tests of a Magneto-Electric Machine. By E. C. Pickering and D. P. Strange. *Proc. Amer. Acad.*, x, 432; *Electrical News*, i, 14, 54.

VII. Answer to M. Jamin's objection to Ampère's Theory. By W. W. Jacques. *Proc. Amer. Acad.*, x, 445.

VIII. An Experimental Proof of the Law of Inverse Squares for Sound. By Wm. W. Jacques. *Proc. Amer. Acad.*, xi, 265.

IX. Diffraction of Sound. By Wm. W. Jacques. *Proc. Amer. Acad.*, xi, 269.

X. Comparison of Prismatic and Diffraction Spectra. *Proc. Amer. Acad.*, xi, 273 (June, 1875).

XI. On the Effect of Temperature on the Viscosity of Air. By S. W. Holman. *Proc. Amer. Acad.*, xii, 41.

The following articles were published in the Report of the Physical Laboratory for the year 1871–72.

The first four are Reports of the Civil Engineers of the Fourth Year in the course referred to above.

Report upon Experiments on a Queen-Post Truss and its component parts. By Messrs. C. S. Ward and B. E. Brewster.

Measurement of the Angular Deflection of Beams fixed at one end. By Mr. C. F. Allen.

Apparatus for ruling lines with a Diamond. By Mr. C. F. Allen.

Coefficients of Efflux. By Messrs. W. B. Dodge and W. E. Sparrow.

Buoyant effect of a column of heated air from a Bunsen burner. By Mr. C. K. Wead.

Law of Lenses. By Mr. C. K. Wead. The focal length of two or more lenses separately and combined, were here measured.

Photometric Experiments. By Mr. C. K. Wead. The light cut off by 1 to 7 plates of glass was measured, also the absorption of ground glass. Another series of experiments gave the light of an Argand burner with various consumptions of gas.

To find the Refractive Formula (that of Cauchy) for any Substance. By Mr. F. W. Very.

Micro-photography. By Mr. C. S. Minot.

Saccharimetry. By Mr. F. A. Emmerton.

Of the unpublished papers may be mentioned the following: —

On Covering Steam Pipes. By several students, collated by Mr. B. H. Locke.

Magnetization by Frictional Electricity. By Mr. C. K. Wead.

Electricity generated by a Holtz Machine in absolute measures. By Mr. S. J. Mixter.

On the Density of the Earth. By Mr. J. B. Henck, Jr.

Measurements of Plateau's Soap-Bubble Films. By Mr. W. E. Nickerson.

Velocity of Air Currents at various distances from an Air-jet. By several students.

Resistance of Water in Pipes. By several students.

Measurement of curvatures and minute distances by Newton's Rings. By Dr. C. H. Williams.

Law of Vibration of a Tuning Fork. By Mr. S. H. Wilder.

Effect of the Intensity of Sound upon its Velocity. By Mr. W. W. Jacques.

It remains for me to speak of my own work, which I do without hesitation; first, since the reputation of the Institute is largely that of those connected with it; and, secondly, because the intellectual as well as the physical results of my work should be in the possession of the Corporation of the Institute.

As the entire work of building up the Physical Laboratory, making or having made the apparatus, and conducting the exercises has been in my hands, unaided by any assistant, I have had less time than I desired for original investigation. Besides this, I have given all the other courses described above, except where the contrary is expressly stated, and, in addition, have delivered four Lowell Courses of lectures. The first of these, on Sound, was in 1869–70; the second, on Experimental Physics, in 1871–2, gave a class composed mainly of teachers, an opportunity to learn the methods of our Laboratory; the third, on the Applications of Electricity and Magnetism, was given at the Lowell Institute in 1873–4; and the fourth, on Lantern Projections, in 1874–5, was especially designed to aid teachers in using this instrument. In 1872 the laboratory was kept open during nearly the entire summer, and instruction in its methods given to a class of half a dozen gentlemen, mostly Professors of Physics in Western colleges. Although the number of regular students in physics has been small, as was to be expected, there have been every year several special students, some of whom devoted almost all their time to physical investigation. To provide work for them, many of the researches I should otherwise have undertaken myself I have put in their hands, and this proved an additional drain on the limited number of subjects of investigation which will occur to a single individual. My principal work has been the publication of the two volumes entitled "Elements of Physical Manipulation," which embody the experiments performed in the current work of the Laboratory. During the summer of 1869, I accompanied the Nautical Almanac Expedition to Iowa to observe the total eclipse of the sun of August 7th. In 1870, through the liberality of the Government of the Institute, I was enabled to

accompany the Coast Survey Expedition to Spain, to observe the total eclipse of the sun of December 22d. The summer of 1873 was largely devoted to observations, with a new form of polarimeter, on the light of the sky and that reflected and refracted by plates of glass. During the summer of 1876 several thousand observations were taken of the heights of the White Mountains with a micrometer level. The results, which will probably supply the most complete survey yet made of this region, are now in process of reduction. The following list gives the references to the published accounts of these researches, together with the more important of my other published papers: —

Dispersion of a Ray of Light refracted at any number of Plane Surfaces. *Proc. Amer. Acad.*, vii, 478 (April, 1868).

Essay on the Comparative Efficiency of different forms of the Spectroscope. *Amer. Journ. Sci.*, xlv, 301 (May, 1868).

Description of a Machine for Drawing the Curves of Lissajous. *Journ. Frank. Inst.*, lvii, 55 (Jan., 1869).

Plan of the Physical Laboratory. (April, 1869.)

A New Form of Spectrum Telescope. *Engin. and Min. Journ.* (July, 1869).

Report on the Total Eclipse of August 7th, 1869. *Journ. Frank. Inst.*, lviii, 281 (Oct., 1869). Trans. into French in *Les Mondes*, xxi, 573.

Observations of the Corona during the Total Eclipse. *Phil. Mag.*, xxxviii, 281 (Oct., 1869).

Note on the Supposed Polarization of the Corona. *Journ. Frank. Inst.*, lviii, 372 (Dec., 1869).

On the Diffraction produced by the Edges of the Moon. *Journ. Frank. Inst.*, lix, 265 (April, 1870).

Polarization of the Corona. *Nature*, iii, 52 (Dec., 1870).

Spectrum of the Aurora. *Nature*, iii, 104 (Dec., 1870).

List of Observations of the Polarization of the Corona. *Journ. Frank. Inst.*, lxi, 58 (Jan., 1871).

The Graphical Method. *Journ. Frank. Inst.*, lxi, 272 (April, 1871).

Photographing the Corona. *Journ. Frank. Inst.*, lxii, 54 (July, 1871).

On Dispersion, and the Possibility of Attaining Perfect Achromatism. *Proc. Amer. Assoc.*, xix, 62 (Aug., 1871).

The Eclipse of 1870. *Old and New*, iii, 634 (May, 1871).

Report of Observations of the Total Eclipse of the Sun of Dec. 22d, 1870. *U. S. Coast Survey Report*, 1870, 115, 229.

Report on the Physical Laboratory. 1871.

A Geometrical Solution of some Electrical Problems. *Journ. Frank. Inst.*, lxvi, 13 (July, 1873).

Applications of Fresnel's Formula for the Reflection of Light. *Proc. Amer. Acad.*, ix, 1 (Oct., 1873).

Measurements of the Polarization of Light reflected by the Sky and by one or more plates of glass. *Amer. Journ. Sci.*, cvii, 102 (Feb., 1874); *Phil. Mag.*, xlvii, 127 (Feb., 1874).

Applications of the Graphical Method. *Proc. Amer. Acad.*, ix, 232 (May, 1874).

Graphical Integration. *Proc. Amer. Acad.*, x, 79 (Oct. 1874).

Mountain Surveying. *Proc. Amer. Acad.*, xi, 256 (Jan., 1876).

Height and Velocity of Clouds. *Proc. Amer. Acad.*, xi, 263 (Jan., 1876).

Comparison of Prismatic and Diffraction Spectra. *Proc. Amer. Acad.*, xi, 273 (June, 1875).

Elements of Physical Manipulation. In 2 Vols. Vol. I, 1873, pp. 225. Vol. II, 1876, pp. 316.

Allow me now to compare the present condition of the Physical Department with that of ten years ago. Then we had only a single room, with a second unfurnished, very little apparatus, and the entire instruction consisted of one course of lectures. Now, besides the lecture-room, we have two large laboratories, one subdivided so as to give five small rooms, and, in addition, rooms for the spectroscope and for photography. The lecture course has been for some years ably administered by Prof. Cross, and a course of lectures on Descriptive Astronomy has been added to it. The apparatus is in good condition, and contains a large collection of slides for the lantern. A large Physical Laboratory has been built up, which now accommodates a hundred students a year. The course has been extended into the fourth year, giving technical experiments to the architects and civil engineers, and to our own students in photography, lantern projections and practical astronomy. Original investigation is encouraged, and numerous articles have been published by our students in the scientific periodicals of the day. The principles on which our work is conducted are few and simple. First, use is of the first importance, appearance, secondary. All our apparatus is based on this fact. Polish and lacquer are dispensed with, and the money saved is expended on the working parts. Secondly, originality on the part of the student is encouraged to the uttermost, and he is taught that, as a scientific man, original research should be his highest aim. Thirdly, there are no secrets in science, and accordingly every aid has been

extended to other institutions desiring to adopt our methods, by giving them the results of our experience.

Of the present needs of the Laboratory the principal one is an endowment to cover running expenses; in this way only can it be placed on a permanent foundation. The apparatus is of the simplest kind, and comprises but few instruments of precision in the modern sense of the term. It has never received the large sum usually expended on original equipment. For the older students, especially in the course in Advanced Physics, a working library of the standard works in physics, and a few of the later scientific periodicals, are much needed. This last need has been in part supplied by the liberality of a friend of the Institute, but where the journals are to be divided among so many departments, each gets but little. Another generous friend has twice given a large sum to the Laboratory, once for a spectroscope, the most powerful ever made at the time of its completion, and, again, by a timely gift, enabled a large sum to be expended on original investigation Several of the most important papers that have issued from the Laboratory resulted from this gift. The Department is also greatly indebted for a most liberal gift for acoustic apparatus. Two large sums have been given for this purpose, and have furnished the lecture course with an excellent collection of instruments to illustrate the laws of sound.

I cannot close this report without an acknowledgement of the aid I have received from you, Mr. President, in bringing our Laboratory into its present state of efficiency. Your confidence in its success from the very beginning, your encouragement and enthusiasm regarding its extension, and the interest you have shown in every detail, have helped, more than we have realized, to such success as we have attained.

My thanks are also due to Prof. Cross, whose work as student, assistant and professor, has been wholly devoted to the interests of our department. To his unwearied efforts the present high efficiency of the lecture course is very largely due.

With hopes that the next decade may witness as great advances as that which is just completed, I remain,

Very respectfully yours,

EDWARD C. PICKERING,

Thayer Professor of Physics.

DEPARTMENT OF PHILOSOPHY.

To the President :—

I have the honor to present the subjoined account of the work done in my department during the past year.

I. WORK WITH REGULAR STUDENTS OF ALL DEPARTMENTS.

During the first half-year, there were given, to the Fourth Year's class, three lectures a week on the Philosophy of Science; to the Third Year's class, two lessons a week on the Rudiments of Political Economy; and to the First Year's class, two lectures a week on the Structure and Analysis of the Sentence.

The course of the Fourth Year's class, on the Philosophy of Science, included discussions of the nature and essential conditions of Science; the distinction between Pure (or Rational) Science and Empirical Sciences; the Classification of existing sciences as belonging to the one or the other of these two heads; the comparative claims of the so-called Pure and Empirical sciences to the character of strict sciences; the exact logical character of the professed "Inductive Logic"; the proper scientific province of all Empirical Investigation; the Observative and Experimental Methods, and their Canons; the restriction of their use to the formation of a Natural History, properly so-called, and their futility as methods of establishing Universal Laws; the formal imperfection of the existing expositions of the Pure Sciences as contrasted with the speculative

truth of their contents; the reduction of the various Mathematical Sciences to one logical system; and the Logic of the Infinitesimal Calculus, with the history and criticism of the several theories of the same.

I take pleasure in reporting the excellent character of the work done by the class upon these subjects. The examination-paper used at the last Semi-Annual is herewith submitted, as indicating better than any general account, such as the above, the nature of the instruction.

FOURTH YEAR. — PHILOSOPHY OF SCIENCE.

SEMI-ANNUAL EXAMINATION, JANUARY 20, 1876.

I.

1. Prove, from the conception of Science as the Ideal of the Reason, that its form consists in the possession by its component judgments, of the three characters of Certainty, Universality, and Unity.

2. In order to establish man's actual possession of *science*, what is it necessary to show? And what, in order to prove that, in any field, he is on the *path* to science, so far as his experience can indicate the path?

3. What is the distinction between Rational and Empirical science? What three other pairs of titles may be given to these groups of human knowledge, and for what reason?

4. Since, by the very conception of Empirical science, it lacks the two most significant characters of the ideal of science, on what rational grounds can we call it science, at all? — what are its claims to scientific character on the ground of certainty, and what on that of universality and unity?

5. Distinguishing between Universality and Generality, state the Final Problem of all empirical science whatsoever. What are the limits of *certainty* in such science? Why does not the process known as Verification change the logical character of empirical science, and raise its method into one of absolute certainty — of real prediction?

6. How many possible Rational sciences are there, and by what titles are they known? Do they actually exist in man's conscious possession? Is the actual form of their exposition consistent with their logical ideal? Why is the number of possible empirical sciences indeterminate? Mention the principal ones thus far developed, in the order (from the highest down) of their degree of scientific developement.

7. Show that Induction, whether in the strict sense or in the modified sense that Mill gives it, is necessarily illusory as a method of certainty.

8. Show that even the introduction of the Principle of Causality

while it substitutes the Deductive for the Inductive form of arguing to the future, fails to bring empirical judgments into the region of certainty.

9. What is the strict province of Mill's so-called Methods of Empirical Science? Into what two Canons are they all at last resolvable? In what natural illusion do these two Canons logically originate?

10. Estimate the Four Methods in respect to comparative strength for determining the problem on which alone they strictly bear.

II.

[Regulars of Departments V, VI, VII, and IX, may omit this part.]

1. State the General Problem of the science *actually* called Mathematics.

2. Give the two grand divisions of this science, with the object of each, and the three subdivisions of the first, with their objects.

3. Distinguish ordinary Algebra from Arithmetic, and Higher Calculus from ordinary Algebra. What different systems of Higher Calculus are actually in existence? What is the distinguishing character of the system called Diff. and Integ. Calculus?

4. By the combination of what two conceptions is the logical justification of this calculus alone possible? What principle alone justifies the neglect of infinitesimals? Does it merely *justify* this?

5. What doctrine regarding the relations between limits is implied in every operation peculiar to the Diff. and Integ. Calculus? To what class of problems is the application of this calculus restricted?

The course to the First Year's class, on the Structure of the Sentence, differed in no material respect from that which has now become habitual in the first half of that year. By a vote of the Faculty after the Semi-Annual, the instruction of this class in the rudiments of Formal Logic was postponed from the second half of the first year to the second half of the third, and this arrangement adopted for subsequent classes. I cordially approve the change. The course of study in logic and cognate branches required of candidates for any degree, will hereafter be as follows: —

First Year, first half, 30 lessons on the Analysis of Sentences.

Third Year, 7 weeks of second half, 21 lessons on Elementary Formal Logic.

Fourth Year, first half, 45 lectures on the Philosophy of Science.

II. WORK WITH STUDENTS OF PHILOSOPHY.

In the department proper of Philosophy, we have had seven students this year — three regular, and four special. Two of the latter were women; and the presence of all four deserves particular mention, as the result of a recent vote of the Government, opening single courses of lectures, in various departments, to students of either sex who might wish to receive instruction without being subject to examination for admission, promotion, or a degree. It is not unlikely that others, and in greater number, may hereafter avail themselves of the opportunity thus afforded; especially, if some public notice should be given of the existence of such courses.

The regular students have continued their historical and critical work upon the modern philosophical systems, following, to such an extent as thoroughness would allow, the course laid down in the catalogue. The year has been occupied, mainly, with a minute study of Kant's *Critique of Pure Reason*, and of Hegel's *Logic*. They have read all the essential portions of these works, and I believe I do not go too far in saying that they have mastered the principles of them. The four special students joined them in their study of that part of Kant's *Critique* known as the *Deduction of the Categories* — its most important and difficult division. The examination-papers used with the regulars during the year, are annexed.

KANT: — CRITIQUE OF PURE REASON.

SEMI-ANNUAL, JANUARY 19, 1876.

I.

1. In what sense does Kant call his principal works *Critiques* of Reason? What does he mean by "criticism" as distinguished from "dogmatism" and "skepticism"?

2. What *historical* connexion is there between Kant and Hume? between Kant and Leibnitz? What is Kant's *logical* relation to these two men respectively? What, to Locke?

3. What innovation did the *Critique of Pure Reason* introduce into the theory of knowing? Show the revolutionary character that Kant

attributed to the innovation, by quoting the substance of his remarks about the "Copernican point of view" in philosophy.

4. What is Kant's prevailing usage, in the *Critique*, in regard to the term *Reason*? In what other sense does he sometimes use it? What does he mean by *pure* reason? In the expressions "theoretical reason," and "practical reason," what still wider (or deeper) sense does he give to the term *Reason*?

5. In what three questions does Kant sum up the whole problem of philosophy? How, in effect, does he answer each of these?

6. What is the purpose of the First Preface to the *Critique*, and what are the successive points brought out in it? Answer the same questions in regard to the Second Preface.

7. On what distinction between the Two Beginnings of knowledge does Kant rest his case against Empiricism? State the distinction, with clearness and fullness. How would you state it in terms of the notions of Sequence and Cause?

8. Has the foregoing distinction any connection with that between Matter and Form, which plays so large a part in Kant's thinking? Justify your answer to this question at length.

9. State Kant's distinction between the *a posteriori* and the *a priori* in knowing. What two other pairs of terms does he use to mark it? What noteworthy difference in his use of the noun *experience* and of the adjective *empirical*? What two meanings given to the adjective *pure* must be carefully discriminated in reading Kant?

10. Starting from the primary distinctions between Object and Subject, and Matter and Form, trace Kant's whole theory of the upbuilding of cognition; show all the elements that he thinks must enter into cognition, the part he supposes each of them to play, and the logical order in which he represents them as acting. Give his criteria for the *a priori* in knowledge, and vindicate, against Hamilton, his doctrine that each of these carries the other and is therefore adequate by itself. Distinguish between Analytical and Synthetical judgments, justify the distinction against the objections of Lewes, show its bearing upon the Problem of Pure Reason, and state that problem in its universal form, giving its three specializations.

II.

1. In how much, with reference to the distinction between Analytical and Synthetical judgments, had Kant been anticipated by others, especially by Locke; and in what consists his contribution to philosophy in connection with this distinction? Illustrate his new view, in connection, particularly, with the Principle of Causality. What new doctrine, referring to this distinction, does Kant establish respecting mathematical judgments?

What are the respective bearings of these two discoveries upon the establishment of the "critical" standpoint?

2. What is your estimate of Kant's attempts, in § 2 and § 5 of his Introduction, to establish our actual possession of some *a priori* cognitions and some syntheses *a priori*? What is the nature, and what the value, of the proofs of these points furnished by the *Æsthetic* and the *Analytic*?

3. Why does the *Critique* contain an *Elementology* and a *Methodology*? Why, an *Æsthetic* and a *Logic*? Compare Kant's view of the twofold in cognition with that of Locke, showing exactly wherein they agree and wherein they differ. Compare Kant's view of Experience with Locke's.

4. Give Kant's "Graduated Scale of Representations," defining its terms as you go.

5. What does Kant mean by "immediacy" in cognition? State, as comprehensively and as accurately as you can, what the fact of Intuition *is*, so far as concerns the Object (Thing in Itself). What, in general, is an "Empirical Intuition"? What does Kant mean by "phænomenon"?

6. Distinguish, after Kant, between *Sense*, *The Senses*, *sensation*, and *empirical intuition*. Is either of these, or is *pure* intuition, an intelligible whole? How is it that we speak of them separately, and apparently define them? To what mental process alone are they conceivable? Make a critical estimate of Kant's theory about the "immediacy" of intuition.

7. In what does the *a priori* faculty (or "Form") of intuitions at last consist? Sketch Kant's attempted proof of this, noticing its waverings from the point, and other defects.

8. Why a "metaphysical" and a "transcendental" exposition of the Pure Forms of intuition? Give the exact distinction between them, taking pains to clear up Kant's peculiar use of the word "transcendental"; and explain the peculiar Method of Proof that signalizes the *Critique*.

9. What remarkable [illegible]ity is there in the Kantian doctrine concerning the Pure Forms of [illegible]tio? [What *should* the doctrine be, for exact consistency with the "critical" principle; and what *is* it, as Kant usually and deliberately states it?]

10. Why is there, in the *Logic*, an *Analytic* and a *Dialectic*? What, in the *Analytic of Conceptions*, corresponds to the distinction between the Metaphysical and Transcendental expositions in the *Æsthetic*? Give the "Logical Table of Judgments" as determined by the Categories, and the "Transcendental Table" of the corresponding Pure Concepts (the Categories themselves).

Make any criticisms that suggest themselves to you upon Kant's so-called "Faculty of Conceptions," and show in what sense only are that and its Categories intelligible. In other words, show the truth and the error involved in Kant's view about the Pure in all cognition, whether intuition or conception.

KANT: — CRITIQUE OF PURE REASON.

ANNUAL, MAY 25, 1876.

1. Make the following distinctions according to Kant: — (1) Between General logic and Special logic. (2) Between Pure logic and Applied logic. (3) Between General logic and Transcendental logic.

2. What are the two main divisions of his *Transcendental Logic*, and what is the object of each?

3. To what in the *Æsthetic* does the [illegible] of the *Logic* correspond in what Kant makes out his so-called transcendental table of the Pure Categories? What would be the name of this part, in the terminology adopted in the *Æsthetic*? With what purpose does Kant precede his "Transcendental" table of the Forms of Judgment by his "Logical" table?

Show the inconsequence of this step on Kant's part, and its inconsistency with the principle from which he sets out upon his investigation of the Categories.

4. Show clearly the bearing of your last answer upon the claim of Kant's final table to the title of "transcendental."

Illustrate, by accurate examples, all the distinctions contained in the Logical Table of judgments.

5. Point out, with proofs, Kant's misconceptions about the subdivisions of the Four Fundamental Categories, (1) as to their mutual dependence; (2) as to the distinction between Negation and Limitation; (3) as to the professed "Pairs" in the sub-categories of Modality.

6. What is the exact object of the so-called *Deduction* of the Categories? To what part of the *Æsthetic* does this part of the *Logic* correspond, and what name might accordingly be given to it? What difficulty presents itself, on undertaking the *Deduction*, that did not arise in the corresponding part of the *Æsthetic*?

7. Why is this difficulty inevitable, with Kant's general presuppositions? What does its necessary existence prove, not only in regard to his *prime* presupposition, but in respect to his hypothesis of the difference in *kind* between the "two main sources of knowledge"?

8. Give Kant's attempted distinction between the Intuition-Object and the Experience-Object; — between the two meanings of "Nature."

9. What, in the most general terms, is Kant's offered solution of the problem of the *Deduction*? Is the minor premiss of his syllogism valid or not? Give your reasons.

10. In arguing for this minor, what is the special form of treatment that he adopts in his *Prolegomena to any Future Metaphysic*?

11. What is the treatment most prominent in the First Edition of the *Critique*?

12. And what the one most prominent in the Second Edition?

13. Explain Kant's doctrine of the "Synthetical Unity of Apperception," and its supposed bearing upon the problem of the *Deduction*.

14. What equivoque presents itself in Kant's dealing with this "Synthetical Unity"? Which side of the dilemma ought he to assume, to make the said "Unity" valid for the purposes of *Deduction*? Why can he not consistently assume this side?

What is the bearing of the whole situation respecting the "Synthetical Unity" upon the real character of his "transcendental" in cognition?

10. Show the rise of "The Three Ideas" — Absolute Subject, or The Ego; Absolute Cause, or God; Absolute Total, or The World — out of the analytic of the Three Forms of Inference, viz., the Categorical, the Hypothetical, and the Disjunctive.

16. Into what three corresponding parts is Kant's *Dialectic* divided, and what is the line of its movement in each part?

HEGEL.

ANNUAL, MAY 30, 1876.

1. Distinguish and illustrate the Three Attitudes of Thought toward the Objective World.

2. Summarize Hegel's critiques, (1) of Dogmatism, (2) of Skepticism, both Empirical and Transcendental, (3) of Intuitionalism.

3. State the Hegelian distinction between a *Beginning* and a *Principle*. How many possible distinct Beginnings are there in Philosophy, and why? What is Hegel's *First Principle*? Under what conditions only can this be made a philosophic beginning?

4. What are the general divisions of Philosophy, according to Hegel, whence deduced, and what writings of Hegel's correspond to them respectively?

5. What is meant by *Dialectic*? Point out the truth and the defect in Kant's view of dialectic.

6. Illustrate the universality of dialectic, as shown in the processes of the Objective World, (*a*) of Nature, and (*b*) of Spirit — man's works, the institutions of Reason.

7. Illustrate the same as shown in the Subjective World, (1) in the growth of the individual mind, (2) in the History of Philosophy.

8. State Hegel's doctrine of the *Notion* as the unit of empirical thought, and trace the dialectical rise of this doctrine out of Kant's "Analytic."

9. State the doctrine of the Immediacy and the Mediation of the Notion, and show the origin of this from the dialectic of Kant's "Æsthetic and "Analytic."

10. In what element of Hegel's general philosophy does the truth of Kant's "Transcendental Unity of Apperception" and "Ideas of the Pure Reason" come to light? Define this element as thoroughly as you can.

11. What are the exact subject and purpose of the *Logic*? What error in regard to them must be carefully avoided?

12. What is the *Method* of the Logical Process, according to Hegel, and what are its "moments"? Into what parts does the *Logic* divide itself in accordance with this method, taken at its origin in the "moments" of the IDEA?

13. What is BEING, in its total finitude or determinateness, in terms of Absolute Idealism? What is THOUGHT — empirical *thinking* — in terms of the same? And what, in like terms, is REALITY — the Concrete Universal of Being?

14. Discriminate between this doctrine of the ABSOLUTE IDEA and (1) The Pantheism of Spinoza; (2) the Pananthropism of Fichte; (3) the Nihilism of Schelling's earlier writings.

15. Illustrate the dialectical process of the *Logic* by sketching the movement through the first triad — Being, Nought, Becoming.

In addition to the study of Kant's and Hegel's text, the class have completed those portions of Schwegler's *History of Philosophy* which cover the period from Kant to Hegel inclusive, and also the parallel portions of Ueberweg. They have also read Mahaffy's rescript of the *Æsthetic* and the *Deduction*, and considerable portions of Stirling's *Secret of Hegel*. One member of the class made, besides, an extended study of Fichte, reading the English translations of his *Science of Knowledge*, *Sun-clear Statement*, *New Introduction*, *Criticism of Philosophical Systems*, and *Vocation of Man*, together with sundry commentaries and his biography.

Theses have been presented by the class, at various times during the year, on the Life and Writings of Kant, the Influence of Kant upon subsequent Philosophy, and the Derivation of Fichte's System from Kant's.

At the Annual Examination in May last, two of the class — Messrs. David Warren Phipps, of Boston, and Robert C. Ware, of Marblehead, completed their course and received the corresponding degree. The third member passed his examinations, but was prevented from completing his thesis by severe

illness. The subjects of the theses by the two graduates, were "Kant's *Æsthetic*: a Restatement of it, with Criticisms," and "The Historical and Logical Relations between Fichte and Kant." In the former, some new points, of apparently permanent significance, are made in the criticism of Kant. Abstracts of both theses will be found on the appropriate pages of the President's report.

Respectfully submitted,

GEO. H. HOWISON.

Boston, Sept. 11, 1876.

DEPARTMENT OF MODERN LANGUAGES.

REPORT FOR 1875–6.

President Runkle,

DEAR SIR: — Permit me to present herewith the report of the department of Modern Languages for the school year 1875–6.

FRENCH REQUIREMENT FOR ADMISSION.

The following table exhibits the results of the entrance examinations in French for the four years that the same has been one of the requirements for admission to the school, the autumn examination of 1876 being included.

1873	1874	1875	1876	
70	41	71	43	No. of students in First Year.
53	49	53	57	Average mark at Entrance Examination.
15	5	3	0	No. admitted without French.
49	26	51	25	No. admitted without conditions.
81	66	61	65	Average mark.
21	15	20	18	No. admitted with conditions.
10	19	32	33	Average mark.

From this it appears that there has been a gradual improvement in the manner in which the requirement has been fulfilled, as indicated in the following particulars:—

1. The average mark of the whole class has slightly increased.

2. The number admitted without any French has constantly diminished, until the present year, when there were none.

3. The average mark of those admitted under condition has constantly increased.

It is to be mentioned moreover, that there has been twice a small increase in the amount required. The requirement at present is; in grammar, "through regular and irregular verbs," that is the more prominent and essential principles of the same; and in reading, "the first two books of *Charles XII*," that is about sixty pages. As will be seen from the last examination paper for admission published in the annual catalogue, and also from the statements and suggestions regarding the preparation in French also contained there, it is only the prominent and essential facts of the language that are required of the candidate. But it is expected that he will know these facts well and have them at ready command.

Each candidate is also examined in pronunciation, in so far as to pronounce a short passage, and his performance of the same is noted with reference to three or four facts of French pronunciation, and judged accordingly. Deficiency in fluency, general style of pronunciation, and minor matters are not counted against him. But, as the marks show, the performance of candidates on so moderate a test, falls considerably below that on the written paper. A fair understanding of and familiarity with the prominent facts of pronunciation can be obtained without great difficulty, and the matter is one of considerable practical importance in the farther prosecution of the study.

At present, the amount of French which students have on entering, can hardly be said to represent a year's work, and it would seem to be more advisable to insist upon greater thoroughness in what is now required, than to add to the amount of the same.

It may be interesting to notice, that of the fifty-eight candidates, as regular and special students, for the FIRST YEAR at the last examination, forty-four stated that French was a regular study in the school where they prepared, and, thirty-five that Latin also was, while thirty-eight reported that they had studied Latin.

WORK OF THE PAST YEAR.

The number of exercises per week in the department were 31 the first term, and 28 the second. The following view shows what was read and the amount:

FRENCH.

First Year. "Bôcher's Reader," 100 pages. "Les chemins de fer" — Guillemin, 100 pages.

Second Year. Mérimée — "Lettres d' Espagne," 50 pages. Taine — "Notes sur l' Angleterre," 150 pages. This class had French exceptionally the first half of the year, in consequence of the omission of one of their courses in another department.

Fourth Year (first half.) "Bôcher's Reader," 100 pages. About — "Roi des Montaignes," 50 pages.

GERMAN.

Second Year. "Whitney's Reader," 34 pages. Grimm's "Märchen," 67 pages.

Third Year. "Whitney's Reader," 55 pages. "Wind und Wetter" — Lommel, 25 pages. "Eigensinn"—Benedix, 22 pages. "Die Braune Erika" — Jensen, 55 pages.

Fourth Year. (students in Sci. and Lat. and Philosophy.) Portions of Schiller's "Wallenstein," and two easy comedies.

Exercises in composition, written and oral, and on the forms and principles of the languages in question, have accompanied the above work in translation.

During the second half of the year, the students in Science and Literature, and Philosophy, pursued, as indicated in the catalogue, a course in the *Science of language*, using as text book Whitney's "Language and the study of language." During this half also there was an optional class of three students, that commenced Italian.

Certain students of the FIRST YEAR, who were admitted on condition in French, and who were much behind the other members of the class, were formed into a class by themselves, reciting oftener than the rest. This Elementary class numbered seventeen, and was united with the regular FIRST YEAR at the Semi-Annual.

TECHNICAL READING.

As indicated above, popular works of a scientific nature have been used to a considerable extent for reading in both French and German. These seem to interest the students more than works of a purely literary nature, and convey practical information, bearing more or less directly on the special profession of the same. Strictly professional and technical reading would hardly be practicable in a class made up of students pursuing different professional courses, and where the main object is to obtain a knowledge of the language. Exercise in such technical reading would be in place in each special department.

Following are the examination papers at the Annual, of the FIRST YEAR in French and THIRD YEAR in German, with the average mark of the whole class on the same.

Respectfully submitted,

CHARLES P. OTIS.

October, 1876.

[EXAMINATION PAPER OF THE FIRST YEAR AT THE ANNUAL.]

Number of students 62. Average mark 64.

I. *Translate.* — Il s'agissait d'ouvrir entre Modane et Bardonèche une galerie souterraine qui, partant de la vallée de l'Arc, allât déboucher en Italie, sur le versant opposé, dans la vallée de la Dora. 12,220 mètres à franchir, voilà pour la longueur du tunnel; une épaisseur de 1800 mètres de roches, voilà pour la profondeur. Vous rendez-vous compte, maintenant, des difficultés de tous genres que rencontre le percement? Avant que les deux têtes du souterrain puissent être reliées par une galerie de 12,000 mètres et qu'un courant d'air s'y établisse, l'air pur manquera mille fois aux ouvriers, dans un milieu vicié tout à la fois par leur respiration, par la combustion des lampes et par celle de la poudre. GUILLEMIN.

1. Indicate the relation to the verb of all nouns and pronouns in "*Vous rendez-vous compte des difficultés que rencontre le percement.*"

2. Point out and explain any instance of the subjunctive you see in the translation above.

3. Account for the ending of the participle in *puissent être reliées* and render in French "*the difficulties which we have met up to this day.*"

4. Explain the forms *s'agissait*, *partant*, *allât*, *puissent*, giving the principal parts of each.

5. Conjugate in full the present subjunctive of *ouvrir, aller*, and imperfect subj. of *rencontre* and *puissent*.

Translate. — The engineers fear that the workingmen may suffer from want of air. Unless a current of air is established, the men will not be able to work. Is it true that they are to build an iron bridge over the Hudson.? I think they will build one.

II. *Translate.* — Puisque je vous ai dit un mot du choix de l'eau c'est le moment de parler de celui du coke.

Une seule question, interrompis-je, ne brûlez-vous donc jamais de houille, ni de bois.—

— De bois, cela ne m'est pas arrivé. J'ai ouï dire toutefois qu' à l'étranger, en Amérique, en Allemagne, on chauffe les machines au bois. Quant à la houille, si elle est un peu grasse, elle gêne le tirage, dans tous les cas, elle donne trop de fumée. On la réserve pour la conduite des trains de marchandise. Jadis on nous donnait des cokes de médiocre qualité, aujourd' hui les compagnies s'attachent à nous fournir les meilleurs combustibles: ce n'est pas nous qui nous en plaignons, demandez plutôt à mon chauffeur.

GUILLEMIN.

1. Why the compound of present in "*je vous ai dit*," the preterit in "*interrompis-je*," and the imperfect in "*on nous donnait*," etc.

2. What is the English equivalent of "*on chauffe les locomotives*;" give this sentence another construction without changing the meaning.

3. Give the principal parts of the verb *plaignons*.

4. Explain the form of the demonstrative pronouns *celui* (*du coke*), *c'* (*est le moment*), *cela* (*ne m'est pas arrivé*).

Translate. — We used to heat our house with coal, now we heat it with steam. Rails are being laid rapidly. He complained of the poor quality of the coal that was given him.

III. (*Passage not translated in class*). — Un certain jour d'automne, Mattéo sortit de bonne heure avec sa femme pour aller visiter un de ses troupeaux dans une des clairières du mâquis. (1) Le petit Fortunato, son fils, voulut l'accompagner, mais la clairière était trop loin. D'ailleurs, il fallait bien que quelqu'un restât pour garder la maison; le père refusa donc. On verra s'il n'eut pas lieu de s'en repentir.

Il était absent depuis plusieurs heures, et le petit Fortunato était tranquillement étendu au soleil, regardant les montagnes bleues, quand il fut soudain interrompu dans ses méditations par l'explosion d'une arme à feu. Il se leva et se tourna du côté de la plaine d'où partait ce bruit. D'autres coups de fusil se succédèrent, tirés à intervalles inégaux et toujours de plus en plus rapprochés; enfin, dans le sentier qui menait de la plaine à la maison de Mattéo parut un homme; ——— il venait de recevoir un coup de fusil dans la cuisse. (2)

MÉRIMÉE.

(1) glade; (2) thigh.

1. Explain the forms *restât, fut interrompu, se succédèrent.*

2. What is the force of the preposition à in *arme à feu*, of *de* in *coup de fusil* and in *venait de recevoir.*

3. Point out in the translation one or two instances of an infinitive not preceded by any preposition and give the rule for it.

4. Give the compound of present of *aller, verra, se succédèrent.*

5. Conjugate the present indicative of *voulut* and *se repentir*, the future of *parut* and the present subj. of *venait* and *recevoir.*

Translate. — Setting out in the morning he went to the town to buy gunpowder. He has just left, but he will return after having done his work. On rising he saw a man coming.

IV. *Translate 8 of the following sentences.* — 1. While running, one of the wheels of the carriage was broken. 2. Although this book does not describe all the methods, it gives a good idea of them. 3. I am very glad that you take a trade. 4. We believe that God made the world. 5. It is said that he will be put to death. 6. We wish to know what these workmen are doing. 7. Here the track will have to pass over a river. 8. What direction is to be chosen for that railroad? 9. Could you reach the depot in time? 10. No! when I reached it the train had left. 11. The man whose vanity [illegible]s is dead. 12. I shall remember the Sundays that I spent with them.

First Ye[illegible]y, 1876.

[EXAMINATION PAPER OF THE THIRD YEAR AT THE ANNEX.]

Number of students, 43. Average mark, 61.

I. Und so wuchs steigend die Bewegung nach allen Seiten, und neben Bußen, Gebeten, Klagegesängen und Fasten traf man die allgemeinsten, die umfassendsten Vorbereitungen zu neuen Zügen. Bald fragte man nicht mehr, wer mitgehe, sondern wer zurückbleibe? Und die Zurückbleibenden wurden als feige und weibisch verlacht und verspottet, während Mütter ihre Söhne, Weiber ihre Männer befeuerten und klagten, daß die Schwäche ihres Geschlechtes sie von Heldenthaten zurückhalte. Kaum schien es der Reizmittel zu bedürfen welche die Kirche aus der Fülle ihrer Macht den Pilgern bewilligte: Ablaß, Befreiung von Zinszahlungen, Schutz für die Güter der Abwesenden, u. a. m. Raumer.

II. Außerdem brach ein solcher Mangel ein, daß man sogar Pferdefleisch aß und Pferdeblut trank. Aber ungeachtet dieser schrecklichen Lage hielt Friedrich strenge Manneszucht und bestrafte, selbst nach dem Zeugnisse seiner Feinde, jeden Frevel und jede Unzucht an den Geringeren, jeden Mißbrauch der anvertrauten Gewalt an den Vornehmen. So strenge Mittel kamen indeß nur gegen wenige in Anwendung; im allgemeinen zeigten die Pilger in Noth und Gefahr eine fast unglaubliche Geduld und Ausdauer. Einzelne welche verzweifelnd zu den Türken übergingen und dem Christenthume entsagten, galten für keinen wahren Verlust. Raumer

III.

M. Geschwind! Geschwind!
Rette dein armes Kind!
Fort! immer den Weg
Am Bach hinauf,
Ueber den Steg,
In den Wald hinein,
Links, wo die Planke steht,
Faß es nur gleich!
Es will sich heben,
Es zappelt noch.
Rette! Rette!

F. Besinne dich doch!
Nur einen Schritt, so bist du frei!

M. Wären wir nur den Berg vorbei!
Da sitzt meine Mutter auf einem Stein,
Es faßt mich kalt beim Schopfe! Göthe.

IV. 1. Case and construction of Reizmittel (I); Christenthume (II); Weg (III); of mir, in „folge mir;" of Sinnen, in „umsonst, daß trocknes Sinnen hier die heil'gen Zeichen dir erklärt;" of Mondenschein, den and Mitternacht, in „O sähst du, voller Mondenschein, zum letztenmal auf meine Pein, den ich so manche Mitternacht an diesem Pult herangewacht!"

2. Construction of steigend and feige (I). Is Feinde (II) Subjective or Objective Gen., and why? Geschwind and immer (III) modify what? To what does es (nur) (III) refer? Decline ihre Söhne (I) and keinen wahren Verlust (II).

3. Principal parts of steigend, fragte (I); galten (II); sitzt (III). Inflect Pres. Indic., Active and Passive, of aß (II).

4. Analyze Bewegung, Klagegesängen, Vorbereitungen, bewilligte (I); unausbleiblich, Wiedervergeltungsrecht, Unentschlossenheit, Nothwendigkeit, Wasserstoffgas, Wiederbelebung

5. What is meant by Primitive words? In accordance with what three principles are derived words formed? State four ways in which compound adjectives are formed.

6. Explain the subjunctives mitgehe, zurückhalte (I); wären (III); möchte in „es möchte kein Hund so länger leben;" wären, in „er behandelte die deutschen Gesandten ungebührlich, als wären sie seine Unterthanen."

7. Give the English *historically* connected with Theil, Würde; the endings -heit, -niß, -schaft, -thum; fangen Dach, bleiben, dringen, treten, wachsen, fahren, heben, schlagen.

8 *a.* State what you known about the Hohenstaufen. Which crusade was this, and when did it take place? *b.* From what two points of view can we look at the Faust drama? *c.* State what is said about the Monsoons and Etesian winds.

9. Translate: 1. He told me day before yesterday that he always rose at half past five, was in very good spirits, and worked the whole forenoon.

2. Many houses in our city have been destroyed by the storm, two of which belonged to my uncle. 3. If the farmer had worked over his garden early in the Spring, he would have had much finer vegetables.

V. Hastily she tore[1] herself away from Raymond, and flew out of the door. The gigantic dog sprang after her with a merry[2] bark. At the same moment all weariness returned[3] into the eyes of the Professor as if *poured out*[4] in a stream. His head fell sleepily upon the hay, and in a few seconds fast sleep had overpowered[5] him.

Erica sat outside under the firs,[6] and sang a soft[7] melancholy song, the commencement of which he heard.[8] But farther and farther did it sound,[9] and strange dream pictures took captive[10] his senses. In his study every thing began to grow animate,[11] and rustled[12] about the arm chair on which he sat.

[1]reißen. [2]heiter. [3]zurückkehren. [4]ausschütten. [5]übermannen. [6]die Föhren. [7]leise. [8]vernehmen. [9]klingen. [10]gefangen. [11]lebendig. [12]rascheln.

VI. (Passage not read in class.) Die Frage, ob das Wasserstoffgas athembar sei oder nicht, hatte ursprünglich zwei ganz entgegengesetzte Antworten erhalten. Priestley und seine Partei behaupteten, diese Luft sei irrespirabel, während Scheele und seine Anhänger gerade das Gegentheil versicherten. Das veranlaßte Fontana, den Versuch an sich selbst zu wagen. Er vermischte Wasserstoffgaß mit atmosphärischer Luft zu gleichen Theilen und fand kaum eine Spur von Unbequemlichkeit bei dem Einathmen dieser Luftmischung. im Gegentheil wollte es ihm scheinen, als wenn er dadurch eine gewisse Leichtigkeit im ganzen Körper verspürte, die ihm wohlthat. Dies gelang auch noch, wenn er abwechselnd reines Wasserstoffgas und atmosphärische Luft einathmete. Sobald er aber versuchte, das Wasserstoffgas ganz unvermischt und ohne Wechsel einzuathmen, so stürzte er bewußtlos zu Boden und wäre sicher ein Opfer des Todes gewesen, wenn seine Umgebung nicht rasch zu Hülfe gesprungen wäre und die passendsten Mittel zur Wiederbelebung angewandt hätte Birnbaum.

[1] Hydrogen gas.

LOWELL FREE COURSES FOR 1875–76.

Department of Physics.

To President Runkle.

My dear Sir:—In response to your request, I would state the following facts regarding the lectures given by me in the Lowell Free Courses for 1875–6.

These lectures were designed to furnish a somewhat extended discussion of the topic of light in its various relations to color and to vision in general, the subject being considered both from a physical and physiological point of view. Much of the matter concerning the physiological side of the phenomena under consideration was not, at that time, accessible to the general reader, no reliable English works upon the subject having been published, and only a very limited portion of it had been treated in any public course of lectures in the country.

The attendance upon the lectures (eighteen in number) varied from a minimum number of fifty to a maximum of one hundred and ten, the average number being about sixty.

The following is a list of the principal topics discussed in each lecture.

I. Light considered objectively. Propagation of Light. Undulatory Theory, and recent suggestions regarding it.

II. Reflection, Refraction, Dispersion.

III. Polarization.

IV. Anatomy and Physiology of Human Eye.

V. Sensation of Light. Müller's Principle of Specific Action of Senses. Modality of Sensations.

VI. Constitution of Luminous Spectrum. Theories of Color of Newton, Brewster and Young. Experiments of Maxwell and Helmholtz.

VII. Color Blindness. Field's Chromatic Equivalents.

VIII. Physical Causes of Color. Colors of Luminous Bodies. Colors of Non-Luminous Bodies. Production of Color by Absorption and Internal Reflection.

IX. Production of Color by Metallic Reflection and Dispersion. Turbid Media. Goethe's Theory of Color. Fluorescence and Phosphorescence.

X. Colors Produced by Interference of Light. Phenomena of Thin Plates and Diffraction.

XI. Chromatic Phenomena of Polarized Light.

XII. Compounding of Colors. Modes of Studying Complementary Colors.

XIII. Geometrical Systems of representing color-variations in Hue, Tint and Shade.

XIV. Measurement of Intensity by Photometers. Effect of variations of Intensity on Saturation of Colors. Irradiation.

XV. Persistence of Sensation. Laws of Duration of Impression. Stroboscope and applications.

XVI. Modifications of Excitability. Positive and Negative After-Images. Rate of Excitation of different color-sensations.

XVII. Successive Contrast, its Phenomena and Laws. Simultaneous Contrast. Contrast of Colors of same hue.

XVIII. Simultaneous Contrast concluded. Contrast of Colors of different hues. Chevreul's Law. General Law of Simultaneous Contrast and Explanation of Phenomena.

An examination of the preceding summary of topics will show that Lectures I. — III., inclusive, were devoted to a brief description of the principal facts of Physical Optics, which was a necessary introduction to the matter afterwards discussed.

In this connection I wish to call your attention to an experi-

ment which I was enabled to carry into effect through the generosity of a member of the Corporation of the Institute. In previous similar courses there had seemed to be a great need of some concise statement of the principles of the subject under consideration, to which the audience might be referred. It appeared that a very brief series of printed notes, comprising one or at most two printed pages for each lecture, and containing a brief summary of the results finally attained, without attempting any description of apparatus or experiments, would greatly enhance the value of the lectures to those in attendance. The result of the trial more than justified the expectation, and from the general desire on the part of the audience to keep a complete set of the notes, together with the expressions of many persons as to their service, I am very certain that the value of such notes can hardly be over-estimated. It would be a very considerable addition to our work for the public if this method could be generally adopted in our Lowell Courses.

All of which is respectfully submitted,

CHAS. R. CROSS.

Kant's Critique of Pure Reason. Eighteen lectures for beginners.

President J. D. Runkle: —

The attendance on the first four of these lectures, given Mondays and Wednesdays at 7½ P. M., commencing Nov. 18, which were of an introductory and general character, was about fifty, nearly half of whom were women. The remainder of the course, devoted to instruction upon the details of Kant's text, was of necessity less interesting to many, and the attendance was at once reduced to some twenty-five, who continued however, to the end. Four of the attendants afterwards joined the class in the Department of Philosophy, as special students of the course on Kant there.

GEO. H. HOWISON.

Physiology and the Laws of Health. Eighteen lectures.

At the Lowell Lectures on Physiology and the Laws of Health, at the Institute, in the winter of 1875-76, there was an average attendance of fifty, principally female teachers. The lectures were illustrated by the skeleton, separate bones, models, life-size engravings, diagrams, and tables on the blackboard.

As the main object of these lectures was to teach the few and simple rules of health, so easy to violate, so difficult to return to without great inconvenience and suffering, only so much technical anatomical detail was introduced as was necessary for understanding the laws of physiology and hygiene. Under the bones were dwelt upon the deformities of civilization, distortions of the spine, chest, hips, and limbs, frequently produced by parents and nurses in the child, confirmed by improper attitudes in school, and uncorrected by teachers, from ignorance or carelessness. Under muscles, the natural correctors of the above deformities, the evils of sedentary habits and the dangers of excessive muscular exertion, the latter of which is, in the present mania for athletic sports, productive of great physical injury, were considered at length.

The phenomena of nutrition, beginning with digestion, from the taking in of food to its conversion into blood, were then examined; — including the composition and uses of the various kinds of food, their nutritive qualities, digestibility, and adaptibility to age, season, climate, and occupation, — the chemical, mechanical, and vital processes carried on by the vessels, glands, muscles, and secretions of the different parts of the alimentary canal — absorption of nutritive materials and their conveyance to the heart — their purification in the liver and lungs — the circulation, pulmonary, systemic, and portal — respiration and animal heat — and the final purifications effected through the lymphatic and other glands, the kidneys, and the skin.

The dangers attendant upon abuse of these various organs, their most common diseases, and nature of the means of cure,

were then explained from the standpoint of elementary physiology, not of medical science.

The course ended by a description of the brain, nerves, and special senses, showing how this complicated body is regulated, and may be preserved from danger, if attention be paid to their timely warnings. SAMUEL KNEELAND.

General Chemistry. Twenty-four laboratory exercises.
Qualitative Analysis. Twenty-four laboratory exercises.

The usual laboratory facilities have been afforded this winter to persons of both sexes who desired to study either General Chemistry or Qualitative Analysis, the text books and methods of instruction being the same as employed in previous years, and as described in the last Annual Report.

W. R. NICHOLS.

Heat and its Applications. Eighteen lectures.

President Runkle,

Dear Sir: — In the Lowell course of eighteen lectures on Heat and its Applications, the principal topics considered were as follows: —

I. Older and newer theories respecting the nature of heat. How heat makes itself known. Correlation of forces. Distinction between accepted theories and positive knowledge.

II. Sources of heat. Resisted motion. Rumford's, Joules and Hirsch's experiments on friction and the mechanical equivalent of heat.

III. Conduction of heat by solids, liquids and gases. Non-conductors and their uses. Clothing. Spheroidal state of liquids. Convection. What are suitable carriers of heat.

IV. Radiation. Good and bad radiators. Resistance to radiation. Transcalence. Melloni's experiments on transmission. Tyndall's experiments on the intercepting power of gases and vapors.

V. Absorption, destruction, or conversion of heat. Expansion of bodies. Differential expansion. Thermometers of various kinds.

VI. Pyrometers. Thermomultiplier. Specific heat. Expansion by mechanical means as compared with expansion by heat. Determination of mechanical equivalent by the expansion of air.

VII. Absolute zero. Thermometric scales. Latent heat. Calorimeters. Freezing mixtures.

VIII. Boiling points. Superheated liquids. Nature of vapors and gases.

IX. Solution of gases in water. Distillation. Fractional distillation and fractional condensation. Analytic condensation.

X. Tension of vapors. Superheated steam. Occlusion of gases by metals, charcoal, and coal. Combination of bodies by volume.

XI. Production of heat by chemical action. Fermentation. Respiration. Combustion in air. Combustion in oxygen.

XII. Fuels. Sulphur and sulphides. Combustibles produced by plant life in different geologic...t epochs.

XIII. Progressive changes of vegetables to form peat, brown coal, bituminous coal, anthracite. The manufacture of charcoal.

XIV. Artificial fuels. Gaseous fuels. Siemen's regenerative furnace.

XV. Fireplaces. Altars. Forges. Kilns. Reverberatory furnaces.

XVI. Heating dwellings. Hot water circulation. Steam heating, direct and indirect. Hot air furnaces. Open grates. Stoves.

XVII. Heat as a motive power, or the conversion of heat into motion. Hot air engine. Wind power. Steam power. Water power. Gunpowder engine. Carbonic acid engine.

XVIII. Cosmic heat. Utilizing the sun's heat. Conversion of heat into light. Origin of all force.

Experimental illustrations were introduced as far as possible, but in giving two evening lectures a week in addition to my ordinary daily duties, I could not make as much preparation as was desirable in the way of demonstrative experiments. Whenever lectures require such aids for elucidation I believe it would

be better both for the audience and the lecturer to let the course extend over a greater length of time and have but one exercise each week.

Respectfully yours,

JOHN M. ORDWAY.

Elementary German. Eighteen lessons.

President Runkle,

DEAR SIR: The Lowell course of eighteen lessons in "Elementary German" assigned to me was commenced Monday, Nov. 22, and continued Monday and Wednesday evenings until finished Jan. 19. The average attendance was forty-five, the number at the beginning being a little larger, that at the end a little smaller than this, the number present varying but little from evening to evening. About a third, I should think, of those attending were men, mostly young men.

The object of the course was to present in a concise and clear manner the *more essential facts of the German language*, with *writing and oral exercises* for the sake of practice. It was found necessary to arrange the course and treat the subject quite differently from what would have been practicable with a class of students, at the Institute for instance, of about equal age and attainments and with time at their disposal for preparation and outside work. For, the class of persons who presented themselves for the knowledge in question differed widely from such students in all of these respects. Some were advanced in life, some were young, some had studied German before and were desirous of reviewing the subject, others were beginners, some had time for study outside of the lecture hour others had not, some had had previous training in language others none. It was desirable therefore to pursue a course requiring as little previous knowledge and training as possible, and little or no outside work, while at the same time the instruction was to be of a systematic and thorough character. The especial features

of the method pursued for accomplishing this object were the use of the *blackboard as text-book*, with regular exercises in *German composition and reading*.

Before the hour for the lecture, such essential grammatical *forms and rules* as were embraced by the subject to be studied during the evening were written on the blackboard, in a concise form and one best adapted to catch the eye and impress itself upon the memory. These the class were requested to write down in note books, as also such things in the exposition given of the subject as might seem necessary. After the exposition of the subject for the evening, followed the writing of sentences involving particularly the principles and facts just presented. Such sentences were written by all in blank-books provided for the purpose. At the end of the hour the majority handed in their books, which were examined and returned at the beginning of the next lecture with the errors indicated.

The only trouble in such a mode of working is the difficulty persons, who have not had practice, find in *taking notes* that are reliable in point of accuracy and completeness. This might, however, be obviated by having the class provide themselves with a short manual containing the essential facts of German grammar, to which they could refer for the forms and so much as might be necessary of what was presented in the exposition. In spite, however, of this drawback the class worked with reasonably satisfactory results, as shown by the exercise books and the continued interest in the subject.

Following is given an outline of the lectures, showing the topics treated at each one. It will be seen that, with the exception of the verb, each topic was taken up and finished by itself. Eight of the eighteen lectures were devoted to the *verb*, as being of much more importance in German than the other parts of speech. In the case of the verb alone the treatment was interrupted, the more essential part being presented first, and the subject afterwards resumed, partly for the sake of introducing earlier other topics demanding attention, and partly

in order to give variety to the work. The *order* in which the subjects were presented was different, it will be seen, from that usually adopted in grammars, but one which seemed most natural and most favorable for unfolding the facts of the language, as also for showing in the proper light the *more important* as distinguished from the *less important*.

I. *Pronunciation.*
II. *Articles. Possessive Pronouns.*
III. *Verb*: simple tenses of a verb of the *New conjugation.* (*Demonstrative and Relative Pronouns.*)
IV. *Verb*: simple tenses of a verb of the *Old conjugation.* (*Use of the tenses.*)
V. *Verb*: compound tenses of the new and old conjugations. (*Use of the tenses.*)
VI. *Verb*: *separable verbs.* (*sein* for *haben* as tense auxiliary).
VII. *Order of the German sentence.* (*Inseparable verbs.*)
VIII. *Personal Pronouns.*
IX. *Adjective*: I and II declensions.
X. *Adjective*: "mixed" declension.
XI. *Adjective*: comparison.
XII. *Adjective*: numerals.
XIII. *Noun*: I declension.
XIV. *Noun*: II declension.
XV. *Verb*: passive voice.
XVI. *Verb*: passive voice.
XVII. *Verb*: reflexives.
XVIII. *Verb*: impersonals.

In order to present to the class at the outset, and keep constantly before them the *actual language*, a small selection of very short selections in poetry and prose, the easiest things to be found, were printed and distributed. These served at each meeting as exercises for pronunciation and translation.

Respectfully submitted,

CHARLES P. OTIS.

The Elements of Perspective. Eighteen lectures.

This course consisted of nine lectures and nine lessons, the lessons being taken up with explanations and the examination and correction of drawings made by members of the class, which consisted of about forty persons, men and women. A printed syllabus containing the propositions to be explained was furnished at each exercise.

The instruction differed from that generally given and from that contained in the text books in several particulars, much greater prominence being given to the phenomena of parallel planes than is usual, and use being made of the laws established to determine the perspective of shadows, a subject that has hitherto received but little attention.

In the course of this discussion it was shown that the paramount importance commonly assigned to the horizontal plane and to the horizon line is unnecessary, and that the practice of referring everything to that plane is productive of needless inconvenience. It was shown that every plane has, so to speak, its own horizon, in which all the lines that lie in the plane have their vanishing points.

The well-known method of points of distance, also, which is generally treated as an auxiliary method of but limited serviceability, was shown to be of universal application, and to suffice for the solution of all problems. The developement of this method was shown to lead to the construction of a perspective plan, taking the place of the orthographic plan by the aid of which perspective drawings are commonly made.

The first part of the course was given to the study of the phenomena with the representation of which the art of drawing in perspective is concerned, and to what may be called a *qualitative* discussion of the subject, as distinguished from the *quantitative* discussion which followed, in which the representation in perspective of exact dimensions was explained. This first part of the course was addressed especially to artists and amateurs, to assist them in sketching.

This discussion involved the subject of the so-called errors of perspective and of the discrepancies that are always found to exist between drawings made from nature and those made by the rules of plane perspective. It was shown that drawings made from nature are in fact made in accordance with the rules not of plane but of cylindrical perspective, — what is sometimes called curvilinear or panoramic perspective, — and the principles and methods of this system were explained and shown to coincide in their result with drawings made directly from objects. The relative advantage of the two systems was discussed, the cases pointed out in which each was to be preferred, and the devices and accommodations explained by which the disadvantages of each may be palliated in practice.

The course closed with brief review of other systems, especially of the system of coördinates and of the *Système Adhemar*, to which was added an investigation into the perspective of reflections.

Throughout the course it was maintained that a problem in perspective cannot be considered to be entirely solved unless the solution gives the vanishing point of every line that is drawn, and the vanishing trace, or horizon, of every plane, a solution which the commonly received methods fail to supply.

WILLIAM R. WARE.

ABSTRACTS OF THESES PRESENTED BY GRADUATES OF 1875-76.

DEPARTMENT OF CIVIL ENGINEERING.

Providence Water Works. Abstract by the author, T. Aspinwall, Jr., May, 1876.

The water supply of the city of Providence is taken from the Pawtuxet river. The main pumping station is situated close to the river, on low land, and is called, from the Indian name of the place, Pettaconset.

The machinery for pumping consists at present of two pumping engines, a Cornish and a Worthington Duplex. The latter is only intended for temporary use here. It has a capacity of 5,000,000 gallons, pumped 180 feet high in twenty-four hours. The Cornish engine, however, is permanent and has a capacity of 9,000,000 gallons. The engine house is designed to contain four Cornish engines of like-dimensions. The Cornish engine pumps into a standpipe 182 feet high, connecting with Sockanosset reservoir. The latter has a capacity of 51,156,544 gallons. Its construction, together with that of its gate chambers was described.

The main to the city was then described, particularly at the crossing of Pochasset brook by a triangular truss, and at the Pawtucket river, which the main crosses on iron screw piles.

The reasons for the construction of Hope reservoir were then

stated, the construction of the gate chambers described, and their action explained.

Hope pumping station was next taken up. The engines here are two in number, each being of the capacity of 5,000,000 gallons in twenty-four hours. One is of a pattern designed and built by Geo. H. Corliss, Esq., and the other of a form designed by A. F. Nagle, M. E., of the Providence Water Works and built by the Providence Steam Engine Company.

The paper concluded with a short account of the pipes used in the mains, giving the formula by which the thickness was calculated and a table containing the results of those calculations for every diameter.

Merrimac River Bridge at Nashua, N. H. Abstract by the author, T. W. Baldwin.

I have commenced this thesis with a full description of the abutments, piers and superstructure of the bridge. Next I have calculated analytically and graphically the stresses arising from a uniform live load of 2500 lbs. per foot. Then follows a calculation of the web stresses when the bridge is partially loaded. Having found all the maximum stresses I have calculated the necessary dimensions of the girders and compared them with the actual dimensions. Next I have made calculations to see whether the factor of safety necessary to be used, in order that the working strength of the posts and braces shall be sufficient to withstand the stresses brought to bear upon them, is of proper size. I have finished by inserting a "Bill of Timber and Iron" together with the weight of each piece, in order to compare the actual weight with the weight assumed in the calculations.

I have made two drawings, one of the plan, side and end elevations of one span of the bridge, and one giving on a larger scale some details of the bridge and masonry.

West Chester Park Bridge over B. & P. R. R. in Boston, Mass. Abstract by the author, J. B. F. Breed.

This is a wrought-iron through highway bridge with three roadways and two sidewalks.

It consists of six girders, four of which are lattice girders and two are plate girders.

I have first given a detailed description of the bridge and then proceeded to calculate the maximum stresses in the diagonals and chords of lattice girders and in the flanges and webs of plate girders. This is followed by the determination of the net area of cross-section and the number of rivets required in the different pieces.

The stresses on the floor-beams and stringers are next considered and the requisite size and form of these fixed. Finally I have computed the total weight of the bridge and thus determined the true dead load.

The thesis is accompanied by plates of drawings representing elevations, sections, plan and details of the bridge.

The Buffalo Water Supply. Abstract by the author, H. T. Buttolph.

The city, first supplied by a private company in 1852, bought the works in 1868. There was much need of improvement, in order to fill the wants of the rapidly growing city, and it was thought they could be more fully carried out under the city government.

The improvements to be made, were to furnish the city with a *plentiful supply of pure water*; to supply a district higher than the level of the existing reservoir; and to lay the pipes low enough to avoid the effects of frost, the freezing of the pipes as then laid being a great inconvenience to the people during the winter season.

The first improvement was made by excavating a tunnel under Erie Canal, Black Rock Harbor and under Niagara River to a point 1020 feet from the pumping station on shore; where was erected an inlet pier with the requisite gates to control the supply.

The pier is 30 feet high, 114,662 feet long, 18 feet wide at the base, and the platform is 15.5 feet wide, battering planes intersecting it, which narrow it at the ends. This platform

from end to end is 87 feet in length. The shaft in the pier is 6 feet in diameter and extends down to the tunnel, nearly 60 feet. The tunnel is at an average depth of 17 feet below the bed of the river, and has a section 8 feet square. The tunnel was five years in building; many obstacles being met, the principal of which were the great leaks of sulphur water. These leaks were encountered at two separate times; the first about 500 feet from Black Rock Harbor, where the water came up through the bedrock, which is a very soft limestone, at the rate of 3500 gallons per minute.

By putting in a wrought iron shield, 6 feet in diameter and 24 feet long, the flow of water was nearly stopped; and the work was carried about 89 feet farther where the second and more disastrous leak was met with. Here the water came in at the rate of 4500 gallons per minute, and the leak delayed the progress of the work nearly fifteen months. During this time the contract of the work passed into other hands.

Ten Blake pumps were put into the bottom of the shaft on shore. Five were put into operation with a capacity greater than the flow of water and by this means the water was kept out of the tunnel, so that the work was carried on. Above the strata through which the water flowed there were harder ones, and after overcoming the second leak the tunnel was raised three feet, top and bottom, in order to carry it through the harder rock.

The formal announcement of the completion of the work was made November 6th, 1875; the work was begun on the 12th of May 1870.

In 1870 the Holley System was introduced to supply the higher district. And in the spring of 1874 over three miles of pipe was taken up and relaid, the bottom of the new trenches for the pipe being six feet below the grade of the streets.

The pumping is at present done by a Compound engine, Shepard engine, and Worthington duplex engine; each of the capacity of 10,000,000 gallons in twenty-four hours. The last named engine does the principal part of the pumping, the Com-

pound doing the least and in the place of which there is being built a Worthington duplex engine of 15,000,000 gallons capacity. The Holley pump takes its supply from the main, through which the engines at the pumping station force the water to the reservoir.

During the winter of 1872–3 the city was twice left without a supply of water, once for nearly forty-eight hours. A protracted east wind forced the water out of the harbor and left the waters in the pumping wells below the reach of the pumps. When the wind changed the water rose again. This trouble can not come up, under the present condition of the works.

The Bridge over Front St., in the Viaduct at Worcester, Mass. Abstract by the author, Fred'k K. Copeland.

After a short description of the bridge and the conditions under which it was built, the dead load was approximately calculated.

The stresses in the web members were calculated for both live and dead load and the results combined. Having obtained the stresses in the trusses, the area of the cross-section required was compared with that actually provided, which showed at once any deficiency in strength of any part. The rivets and pins were calculated both for shear and bearing; the number of rivets used, in all cases, was largely in excess of the number required.

The posts were calculated by "Gordon's formula"; their area being given, their ultimate strength, and from this the factor of safety used was calculated, the smallest value of the latter being over four. The floor beams are plate girders hung from the trusses by suspending straps. These beams were very heavy as the bridge carries three tracks, and it was not possible to have more than two trusses.

The amount of iron used was found to be sufficient in all but a few parts and in these the deficit was not large. The weight

of iron was calculated and proved the dead load to be less than the dead load first assumed.

The Broadway Draw Bridge, Boston, Mass. Abstract by the author, John R. Freeman.

The first part of this thesis is mainly descriptive, the general form of the pier and superstructure and the form and dimensions of the more important members being explained with reference to the accompanying drawings, and the manner of building the foundation for the centre pier and of depositing the concrete in the depth of water there existing being briefly described. Some of the more important requirements of the specifications as to character of work and quality of materials and the results of tests made to determine the strength of the wrought iron used, are also given.

The maximum load assumed in the specifications is then discussed and next the conditions of loading producing maximum stress in a continuous girder of two spans are investigated. Then starting with the "Theorem of the Three Moments" as given by Weyranch, a formula for the end reaction for this case is derived.

The method used for the determination of the stresses in the different members is that known as "Ritter's Method of Sections". The maximum intensity of stress in each member is then found, and compared with the limit fixed by the specifications.

The remainder of the thesis is taken up by a calculation of the stresses in floor beams, etc.

Accompanying the thesis are three sheets of drawings, showing the whole structure in plan and elevation and the more important parts in detail.

The Albany Street Bridge in Boston. Abstract by the author, F. W. Hodgdon.

The thesis begins by giving a general description of the bridge which is to replace the old iron lattice bridge on Albany Street.

It is to have four trusses 10 feet high and of spans varying from 102 feet to 83.7 feet. They are double Warren girders and the floor beams rest directly on the lower chords. The trusses are held in position by angle bar stays. The roadway is 32.5 feet wide, and each sidewalk is 8′ 9″ wide, making a total width of 50 feet. It is calculated for a load on the roadway of 80 lbs. per square foot live load, and 90 lbs. per square foot dead load, on the sidewalk 100 lbs. per square foot live load, 50 lbs. per square foot dead load.

Then it takes up the calculations, explains the method, and finds the stresses in all the parts.

Using 9000 lbs. per square inch for compression and 8000 lbs. per square inch for tension, it finds the sectional area required for each piece, and compares it with the actual area used, and gives the sizes and shapes of all the iron used in making up each cross section. Everything is reduced to tabular form where possible.

Finally it takes up the subject of riveting, explains the principles and shows its application in the case of this bridge.

The drawings which accompany it show, I. Elevations of each of the four trusses; II. A cross section of the bridge, a skeleton plan and the principal details.

Iron Bridge over the Merrimac River, at Tyngsboro, Mass.
Abstract by the author, A. L. Mills.

In this thesis, I have first given a short description of the bridge and its foundations. I have then given a statement of the loads for which this bridge was calculated, which I obtained from the Engineer, Mr. C. H. Parker.

I then calculated the greatest stresses that could occur on the members from different positions of the live load, giving an explanation of the method used in the calculations. I have found the actual stress in pounds per square inch of section and compared it with the breaking stress per square inch, showing the factor of safety that is in actual operation in the different parts of the bridge. In all cases of compression members I

have used Mr. Gordon's formula for the breaking stress in pounds per square inch. For the tension members I have taken the tenacity of wrought iron rods between 60,000 and 70,000 lbs. per square inch, as given by Rankine. For wrought iron plates I have used, on the same authority, between 50,000 and 60,000 lbs. per square inch as the breaking stress.

I have treated the floor beam, which is a "Pratt" truss of six panels, in the same way that I have treated the main truss.

I have found the stress per square inch on the wooden stringer which lies between the floor beams, and have found it amply strong enough to sustain the load it was intended to bear. Lastly I have calculated the weight of the iron work and planking in the bridge, showing that the dead load was estimated but a trifle too large.

Design for a double track Wrought Iron Post Truss. Four Girders. Abstract by the author, Henry Raeder.

In the introduction of my work I have given a general description of the form of a Post Truss, followed by the conditions under which I designed this special case of that kind of truss.

I then explained the method of calculation I employed, which fundamentally consists in dividing one of the four trusses into two primary trusses and afterwards combining the results of the calculations for the two girders.

The chord stresses I found by Ritter's method of sections, and the maximum web stresses from the corresponding shearing forces, when the girder is most disadvantageously loaded for the section in question. I checked the chord stresses by finding them a second time from the horizontal components of the web-stresses under a uniform live and dead load.

Having found the maximum stresses, I designed the pieces which are to sustain them, using for limit of stress in a tie 50,000 lbs. per square inch and employing Gordon's formula $\left[p = 40{,}000 \div \left(1+\frac{e^2}{\frac{(10{,}000)}{40{,}000}\, r^2}\right)\right.$ to find the limit of stress in

the struts. I employed five for the factor of safety. In the remainder of my work I discussed the details of the structure, and finally calculated the entire weight of one girder, and comparing this *calculated* weight with the dead load *assumed* in the calculations, I found it was smaller.

West Boston Draw. Abstract by the author, C. L. Rich.

This pivot bridge consists of two equal Pratt girders of wood and iron, span of 68.5 feet each; width, including sidewalks, 50 feet, and twelve panels in each span. It is continuous over the three level supports, with a uniform cross-section. Two plate iron girders at the centre carry the weight of the bridge to the pivot. A live load in addition would bring the ends of these girders to bear upon the wheels of the turn-table, so that the centre support always acts through the iron girders at the middle. The ends of the bridge when open are supported by hog chains, passing over Samson posts erected over the centre. These rods, by a pin joint in the upper chord, continue to the lower chord, at the same points as the end support.

The dead load is taken as 45 lbs. per square foot; the live load, 80 lbs. The hog chains and the girders of the turntable are calculated for the open condition. The working strength of wrought iron in tension is 10,000 lbs. per square inch; in compression, 8,000 lbs.; in shearing action, 8,000 lbs.; in bearing on rivets, 10,000 lbs. per square inch. The flanges are assumed to resist the bending; the web, the shearing forces. The girders are of uniform strength. In discussing the trusses, the factor of safety of each part has been determined, which shows the relative strength of the parts. This factor may be smaller here, than in case the maximum load is often obtained.

As a check on the chord stresses, a diagram of the moments was drawn, by representing the positive moments by parabolas whose middle ordinates are $\frac{1}{8}$ Wl, where W is the total uniform load on either span, l, the length of span; and the negative moments by triangles, whose altitudes in a total uniform load,

are $\frac{1}{8}$ Wl; when the live load covers only one span, the altitude is $\frac{(W + W^1)l}{16}$, where W and W^1 are the loads uniformly distributed over each span. The ordinates between parabola and triangle in terms of the moments, divided by height of truss, give chord stresses.

In calculating the stresses, the dead and live loads are taken separately. The first thing is to find the reactions, then shearing forces, chord stresses, or the diagonal stresses.

In the bending action, the loads are considered uniform. Moments tending to produce compression in the upper chord, are called positive; those tending to produce tension, negative. The supporting forces or reactions at the left, right and centre are called R_A, R_B and R_C respectively. R_C and therefore the negative moment at centre are maximum under a full load. $R_A = R_B = \frac{3}{8}W$. $R = \frac{5}{8}W$. A half panel load must be deducted from these reactions for shearing forces in the end panels. R_A and therefore the positive moment in the left span, are maximum, and the negative moment extends farthest from the centre, when the left span only contains the live load. Then $R_A = \frac{1}{16}W$, $R_B = \frac{1}{16}W$, $R = \frac{10}{16}W$, W being the uniform live load in the left span, while the reactions resulting from the dead load are those in the preceding case.

Shearing forces, which act upward at the left of any section are called positive; downward, negative. The shearing action of the dead load still remains the same. The live load is treated as concentrated at the 11 apices of the lower chord, and the reaction caused by each is separately calculated by three formulas.

$$R_A = \frac{P}{4}[4 - k(5 - k^2)], \quad R_B = -\frac{P}{4} \cdot k(1 - k^2),$$

$$R_C = \frac{P}{2} \cdot k(3 - k^2).$$

where P is an apex load, and k, the ratio between the distance from left support to the load, in the left span, and the whole span.

By supposing the apex loads attached as we wish, and taking

the sum of the reactions of each, as calculated in the 11 cases, we can get any desired condition. The maximum positive shearing force in any bay of the left span occurs, when the live load extends from the centre support bay; the maximum negative shearing force, when the right span is fully loaded and the live load extends from the left support to that bay.

There are trussed floor beams 12 feet apart carrying two longitudinal beams, which support two intermediate floor beams, extending under the sidewalks. The greatest stress in the sidewalk beams occurs under a heavy wagon load; as 20 tons. The trussed beams carry the greatest load, when under the uniform full load.

A prominent advantage of this bridge is its complete rotation.

The Eastern Avenue Swing Bridge in Boston. Abstract by the author, Henry M. Waitt.

This thesis opens with a short statement of the dimensions of the truss, and the extent of loading. Next in turn comes the calculation of stresses. The bridge was considered as continuous over "Four Level Supports". The dead load was considered to produce the same effect on the truss when shut, as when open. The live load in every case, as acting continuously over the four supports. The four reactions, for each individual panel load, were calculated by the formula given in "Dubois' Graphical Statics", pp. 184–5, Art. 122. Having thus obtained the reactions of every panel weight, the stresses were calculated for various loading, both with, and without snow, and the maximum stresses obtained for all cases. The method of Sections was used exclusively in this work. The method furnishes a ready means of ascertaining the position of counters, and the character of stresses.

Comparison was made with the amount of material in the structure, and, as a general thing, was found to agree well with the calculations. There was, however, one marked exception to the above, and this occurred in the middle bay, where the

upper chord was considerable in excess, and the diagonal ties one half the requisite size. The floor-beams were tested for the maximum moments and shears, and found to contain sufficient material.

The maximum intensity of shearing stress on the web was calculated, and compared with the safe working intensity, given by Gordon's formula. The floor-beam hangers, and the intensity of stress on the wooden stringers, were also calculated. Lastly the weight of the bridge was computed, the result proving somewhat smaller than the assumed dead load. Two sheets of tinted drawings accompany this thesis, the one showing plan and elevation, the other showing end view and details of construction.

On the Haverhill Highway Bridge. Abstract by the author, H. B. Wood.

The bridge consists of five spans in all; one pivot draw of about one hundred and twenty-five feet span; three spans of about one hundred and seventeen feet each; and two spans of about one hundred and two feet each. Each span consists of two principal trusses built after the "Pratt" model.

The roadway is twenty-five feet wide in the clear, and is supported by "built up" cross girders, each of which projects by the vertical posts, so as to form supports for the two sidewalks, which are six feet wide in the clear.

These cross girders are bolted to the vertical posts, and rest upon plate-iron brackets rivetted to the same. The upper chord is built of wrought iron plates and angle-irons, forming a rectangular cross section, open and latticed at the bottom, so as to be easily painted. The lower chord consists of flat bar iron of uniform depth, and increasing in thickness toward the centre of the span. The posts are I-beams rivetted to the upper chord and resting in bearing blocks on the lower chord. The diagonals consist of square and round bar iron with screw ends, and fastened with wrought iron forged nuts, which rest upon

cast iron bearings or angle blocks on the top chords, which abutt against the thrust plates. The "effective" section for use in calculating stresses is taken at the foot of the threads. The cross girders camber six inches in the centre, to form a water shed for the roadway, and are four feet deep at the centre. The cross bracing consists of the cross girders as compressive members, and diagonal tie rods.

Stringers of southern pine (3″ x 12″) are placed upon the cross girders about sixteen inches from centre to centre, and upon these rests a planking of yellow pine two inches thick, and running transversely. Upon this is laid a course of white oak plank, also two inches thick, and butted on the centre line of the driveway, and thence running 45° each way right and left, with this centre line.

The sidewalks have but one course of planking, and are four inches higher than the driveway. The draw is built upon the pivot plan, in which nearly the whole weight is thrown upon the centre pintle, which is adjustable. It has a spider wheel and radial rods, with coned cast-iron wheels upon their ends, running between two coned surfaces on the pier and bottom of turn-table. It is opened by means of a turning bar which fits upon the vertical shaft at the centre.

The bridge is designed to carry a moving load of twenty-six hundred pounds per foot of span, without straining it more than one-sixth of its ultimate strength.

Counters are put in where it is necessary to resist the action of partial loads.

A complete calculation of the stresses in each piece of the first span is given, also the areas of cross sections required, and the actual areas given.

Direct measurements of the structure itself were made, to obtain the latter data.

DEPARTMENT OF MECHANICAL ENGINEERING.

A Mechanical Laboratory. Abstract by the author, A. D. Blodgett.

In this thesis I have endeavored to call attention to the following points, viz.: 1. The necessity for a more extensive Mechanical Laboratory in the city of Boston. 2. Why it is a necessity. 3. What class of people would be benefitted by such an institution. 4. What Institutions in this country and abroad already have in this direction. 5. What they hope to have in the future. 6. What the Massachusetts Institute of Technology already has toward a Mechanical Laboratory. 7. What I think would be a good direction for the development of our Laboratory. 8. Why?

The above points it will be observed are taken up in more or less detail as it has been thought necessary, and I would say that I have copied freely from works on engineering both in our own land and abroad, always making a note of the same and giving the authority for the information in the margin opposite. I have illustrated the thesis with wood-cuts and photographs kindly furnished by the manufacturers of such machinery as will be found mentioned in the text.

Reference has been made to the views whenever it was thought necessary. In the basement room at the Institute represented on Plate II, I have thought it advisable to arrange machinery as there represented. This machinery will be found to consist of Lathes, Planers, Milling Machine, Saws, Drills, Emery wheel, Grinding apparatus, Testing machine, etc.

The power necessary to drive the machinery would be supplied by a belt from the Harris-Corliss Engine described and represented in the thesis.

The width of the belt is also calculated. It passed from the fly wheel of the engine to a large pulley on the main shaft which enters the room above and near the door parallel to Boylston St.

The power would be carried to each machine as represented on Plate II by a belt from the main shaft to a counter shaft for

that machine. The speed of each machine would be adjusted to the speed of the main shaft by the relative size of the pulleys. There is also for each *lathe* a set of cone pulleys which allows certain variations from the main speed.

In reference to the drawings it may be well to state that the scale for Plate I is $1\frac{1}{2}$ inch $=$ 1 foot for all parts of the calorimeter except the figures A and B, these are not drawn to scale. The scale for plate II is $\frac{1}{2}$ inch $=$ 1 foot.

Steam Boilers. Abstract by the author, C. L. Dennett.

The writer's idea in the selection of the subject was, that by giving it the study required in order to present it in thesis form, he would gain a knowledge of the subject that would be practical and useful, and which should be first possessed by the steam engineer, since the subject of steam generation naturally precedes that of steam using.

Various works have been examined in order that the best information on each point might be obtained. Personal observation has also been a material aid.

Among the works consulted may be mentioned, Bargh on "Steam Boilers," Isherwood's Experiments, Wilson on "Steam Boilers," Trowbridge's "Heat and Heat Engines," Bournes' "Catechism of the Steam Engine," Rankine's "Steam Engine," C. Wye Williams on "Combustion and the Prevention of Smoke," W. R. Johnson on the "Practical values of American and Foreign Coals," "Journal of the Franklin Institute," "Master Mechanics' Reports" and others, besides numerous pamphlets on boilers and boiler tests.

The different parts of so extensive a subject are, in the thesis, necessarily presented very briefly. The general heads are as follows. 1. The requirements with which boilers should comply. 2. General form. 3. The natures and strengths of the different materials entering into boiler construction. 4. The strength and construction of the component parts, as the shell, flues, rivets, stays, tubes, etc. 5. The boiler fittings, as grates, furnace doors, pressure gauges, safety valves, blow-off

pipes, gauge cocks, manholes, mudholes, etc. 6. The testing is considered. 7. The boiler setting and general proportions, including chimneys. 8. Boiler management, and injuries to which they are especially liable. 9. The circulation. 10. The subject of incrustation is taken up more fully than any of the previous subjects. The most common injurious ingredients of water are mentioned and different methods of preventing their action upon the plates explained. 11. The subject of combustion is also quite fully taken up. The process of combustion is analyzed; the causes and the waste of imperfect combustion, and the importance of air admission above the fuel are explained. These divisions are more or less fully illustrated by drawings, tracings, and wood cuts. 12. Land Boilers — A — the factory horizontal tubular, the vertical tubular, the fire-engine boiler, the locomotive boiler, and one of the boilers of the Hope Pumping Station at Providence, R. I. These boilers are illustrated by practical examples and the best authorities are cited as to their leading dimensions. B — sectional boilers are illustrated by cuts of the Root, Allen, Phleger, Lowe, Blanchard, Harrison, Wiegand and Exeter. 13. Marine boilers. The results of Isherwood's comparison of the Martin vertical water tube and the English horizontal fire tube boiler are illustrated by outline drawings of these two classes. A complete tracing of a boiler of the U. S. Steamship Vandalia is given and the principal data of its design. Two boilers, one of the U. S. Steamer "Jacob Bell," and one of the U. S. Steam Battery "Monitor" are illustrated by tracings, as being boilers of high efficiency, and the results of Isherwood's experiments on each are given.

Certain Points in the Development and Practice of Modern American Locomotive Engineering. Abstract by the author, Francis E. Gallonpe.

In the study of the Locomotive Engine the subject divides into what are called the theoretical and practical aspects. I may therefore in its treatment first view the practical division

and state what has been accomplished before applying the theoretic principles by which to criticise what the latter has done. In the treatment of the former, an investigation of the efficiency of the locomotive as it exists, has been made. The locomotive is throughout an exhibition of Dynamics, a moving structure. It begins with receiving power as the motion of heat, from the combustion of the coal, and ends with imparting force and producing visible motion of masses of matter. In the fuel from which this is derived, the energy is stored. The primary moving force in the locomotive, heat, is first considered and the manner and amount of its generation in the combustion of coal. The efficiency of the working fluid to which this energy is transferred, succeeds. The efficiency of the apparatus by which this is effected is next ascertained, and that of the mechanism by which the portion of energy utilized in the former is converted into its final form of motion against resistance at the circumference of the wheels. The subject is therefore considered under the following heads: —

In a historical sketch are traced the successive improvements in the development of the Locomotive and the Railway, and the practice with regard to the former from Darwin's "Fiery Chariot" and Cugnot's first actual running locomotive machine, in 1769, to the present time. The performance of these early engines is given and the most important improvements and principles developed in them are stated.

Part 1. The Production of Heat and the Laws of Combustion. The various sources of heat, mechanical, physical and chemical are mentioned, and that of Chemical Attraction, the action of which between elementary substances in the fuel and the oxygen of the air produces combustion, considered. The natural and artificial solid combustibles are stated, and three typical substances employed in locomotives, viz.: — Anthracite Coal, (Lackawanna), Semi-Bituminous Coal, (Cumberland), and Wood, (Dry Pine), considered. Tables showing their composition are given and calculations made of one, Cumberland coal, as follows: — its total heat of combustion, equivalent carbon in

one pound, evaporative power from 212° and 62° Fah., equivalent foot-pounds of work, weight of air necessary to be supplied for complete combustion and for dilution, and the temperature of the fire. In this part it was found just what the fuel that is burned in the fire-boxes of locomotive boilers is, by theory, capable of doing.

Part 2. Water and the Properties of Steam. Of the two distinct operations common to all heat engines, heat making and heat expanding, in the former of these the facts having been ascertained, the latter is here considered. Water is treated chemically, physically and dynamically. The physical properties of steam are enumerated and the subject discussed with reference to three circumstances which determine its condition, its density, pressure and temperature. One pound of saturated steam at atmospheric pressure, at 120 pounds and 140 pounds above the atmosphere, is treated in its generation under constant pressure, and also under volume, its motive power, expansion, condensation and efficiency.

Part 3. An American Passenger Locomotive. The ultimate object of the locomotive-engine is to draw a train of a certain number of cars, upon a specified maximum up-grade, at a certain velocity. In this part a bituminous coal burning passenger engine, built at the Hinkley Locomotive Works in October, 1875, for the Eastern Railroad, was selected, illustrated by five detail drawings and a complete specification given. Its parts were classified and its details and action discussed under the following heads: —

A. The Boiler. 1. The shell, description, construction, material, strength, factor of safety. 2. The Heating Apparatus, the furnace and the tubes. The efficiency of the heating surface and furnace is found and other calculations made concerning its evaporative power. 3. The Feed Apparatus for the supply of water to the boiler consists of the pump and injector. These are described, illustrated by tracings, and the principle of the latter explained. 4. The Safety Apparatus which forms a large part of the locomotive boiler fittings, is mentioned in

detail, and the Steam Gauge and Safety Valves illustrated, described and their mode of construction and principles upon which they operate given. 5. In the Transmission Apparatus by which the power is distributed to the engine, the steam and exhaust pipes are treated and the velocity of steam through them determined.

B. The Engine. In the engine the parts and topics are mentioned as 1. The Cylinder and its proportion; 2. The Valve Gear; 3. The Action of Steam in the Cylinder and the Blast; 4. The Transmission of Power to the Wheels by means of the Cranks and Connecting Rods; 5. The Running Gear; and 6. The balancing of the engine.

In this part the object was to apply theoretic principles to this particular engine and determine what its performance should be. In the succeeding part it is ascertained how nearly it does approach to this theoretic excellence and its actual efficiency determined.

Part 4. Trial of an American Passenger Locomotive. On March 1[illegible], 1876, trips were made upon the engines of two of the fastest passenger trains of the E. R. R. On the first and last of these days I rode from Boston to Rockport, a distance of thirty-six miles, and return, upon engine No. 36 ("The John Howe"). Upon the three intervening days trips were taken to Portsmouth, N. H., a distance of fifty-six miles from Boston, upon the 8.30 A. M. Bangor train, and data taken upon them concerning the actual running of the engine.

The engine was No. 55, being the same as that whose parts are discussed in Part 3. Six tables give in full the data taken upon the latter and results obtained. The observations made were the times of passing all the stations, the steam pressures, the point of cut-off, the coal consumed, the depth of water in the tank, the speed at different portions of the road upon levels, up-grades, curves and against head winds, and miscellaneous notes of the time of stopping, the action of the air-brake, the oiling of the engine, the weather, condition of the rails, direction of the wind and number of cars. In all, records of four

hundred and ninety-five miles run were obtained, and of the engine under consideration three hundred and thirty-six miles. In brief, it was the aim to note every occurrence that took place with regard to the engine. The carrying of a train from Boston to Portsmouth means so many gallons of water and pounds of coal consumed. The tables state what these amounts are. From them other results are calculated, such as the equivalent horse power exerted and the train resistance. The record of the direction and velocity of the wind during these three days was obtained from the Weather Signal Office in Boston, so that the extent of the resistance from this cause could be approximately ascertained at any part of the road. The method of correcting the times for the rate of the watch is explained, the action of the safety valves and method of determining the coal record and of the speed. The capacity of the tank is calculated both from the measurements upon the detail drawings and from actual measurements with a steel tape, of all the accessible parts. A drawing of the tank and its internal staying is given.

Succeeding is a discussion of the peculiar facts shown by these records, and a table is given of the performance of eight engines of the E. R. R., including No. 55, for the month of January, 1876, by which any deviation from the records of ordinary locomotives is plainly seen. The power exerted by this locomotive on a part of the road is next calculated; its weight and tractive power ascertained. The extent of the train resistance is partially discussed. Finally, the efficiency of the mechanism is approximately found.

To sum up, the efficiency of the locomotive is the product of the three factors found and is stated as follows:

1. Efficiency of Furnace and Boiler, ...557
2. Efficiency of Steam, ...071
3. Efficiency of Engine or Mechanism, ...80

Efficiency of the Locomotive Engine, $.557 \times .071 \times .80 =$ .326 or three and two-tenths per cent.

The projects of improvement in the boiler, the mechanism,

and in the use of steam are mentioned, and statements made as to the effect of gauge upon economy in locomotive use. Narrow gauge roads, having the United States Standard gauge of three feet, are rapidly being opened in our State, and to them we look for cheap passenger transportation, rapid speed and economical working.

Paper Mills and Machinery. Abstract by the author, S. Hollingsworth.

After a brief history of the first paper mills in Europe and America, the subject is divided into, and taken up under two principal heads: First the Machinery, and second Mills.

First. The various machines are treated under the heads of the different processes they aid. The processes themselves however are treated only so far as concerns the engineer who designs the mill.

The manufacture of paper from the most commonly used material generally requires the following.

1. To form the pulp from the raw material. Thrashing, sorting, dusting, boiling, washing, draining and beating are generally necessary, and under all these heads, the machines and apparatus are described and shown in sketches, etc. The speed and power required by the most important of them is given. The general arrangement of foundations and rooms that contain them is spoken of. And in the case of the boiling process, results are given of an experiment by the author to find the amount of steam used that the engineer may know what boilers must be used.

2. To form the pulp into paper. The old process of making the paper by hand or from the vat is still practiced in Europe, and is therefore described and a sketch given of some of the apparatus used.

Paper is now formed from the pulp by the so called "paper machine" in some form. Of these there are two kinds in common use, the Fourdrinier and the cylinder machines. The history of the development of the Fourdrinier machine is quite

interesting, and is therefore briefly given. The two machines are described and illustrated, their comparative merits are spoken of; and the questions of amount of steam used in drying the paper by an experiment by the author; the foundation of machine; the room; ventilation; felt-washers; roll-grinders, etc., are brought up.

Second. Under the head of Mills the question of location brings up the questions of communication with the markets; the use of steam or water for power; the quality and quantity of water used in the manufacture; building materials, etc. The whole power required by a mill of a given capacity is given, and also something about the general arrangement of the mill, repair shop, etc.

Pumping Engines. Abstract by the author, Alfred C. Kilham.

Dividing pumping engines into two classes, according as they pump into a reservoir or directly into the distribution, I have first described several engines under ach head. Under the head of Engines pumping directly into the distribution, I have taken the Corliss and the Holly engines and the new engine recently erected at Providence, according to the designs of Mr. A. F. Nagle of that city, and have endeavored to give some idea of their size and character, together with their advantages and disadvantages as regards economy and liability to accident. Under this head are also compared the advantages and disadvantages of the two systems.

Under the head of Reservoir Engines are taken, first, the Cornish; second, the Leavitt, as an example of a beam and fly-wheel engine; third, the Worthington. These are described like those under the first head, the advantages and disadvantages of each variety of engine being pointed out, and a table of the duties attained by each kind of engine being given.

Under the head of Cornish Engines is described "Davey's Differential Valve Gearing," which has been quite extensively ntroduced in England both for Horizontal and Cornish pump-

ing engines. Its object is to make the valve motion not entirely dependent on the piston, but partly on the load, and so to change the point of cut-off that the speed of the piston shall not be very much accelerated or retarded by a change in load, and thus to ensure freedom from accident.

Having described engines under both heads, a comparison is drawn with regard to ultimate economy between the two systems and between the different engines in the same system. From calculation the engines pumping into the distribution are decided not to be economical except for places where not more than 2,000,000 gallons per day at the utmost are required.

From a similar calculation of the first cost and duty of different engines, it is decided that the Leavitt beam and flywheel engine is the most economical engine in this country, it having given both the highest special test duty and the highest annual duty of any engine in this country. On the special test the duty was 103,923,215 foot pounds per 100 pounds of coal consumed, and an annual duty of about 90,000,000 foot pounds per 100 pounds of coal consumed, including coal used for banking, has been obtained.

The Worthington engine, which has been largely introduced throughout the United States, is much valued on account of the apparent ease and quietness with which it performs its duty and its freedom from liability to serious accident; but although it gives good results compared with most pumping engines, it does not approach the Leavitt engine in economy.

Shafting and its Fittings. Abstract by the author, Theo. J. Lewis.

In my thesis I have endeavored to give an account of a research which I have made into the subject of Shafting and its fittings. In this research I have read such books and essays as were at my command, and have taken from them what seemed to me to be the most important facts connected with the subject.

The sources from which the information contained in the

thesis is chiefly drawn are the following: Rankine's "Machinery and Mill work," Weisbach's "Mechanics of Machinery," Fairbairn's "Mills and Millwork," Box's Mill Gearing," Barlow's "Strength of Materials," Anderson's "Strength of Materials," Essays upon Shafting by Messrs. Allen, Hussey, Burke and Francis in the Report of the New England Cotton Manufacturer's Association, Essay upon Shafting by Mr. Coleman Sellers, "Fittings for Line Shafts" in the Engineering.

The subject is treated of in the following manner: —

1. The older forms of shafting and the various improvements which have been made upon them, as the introduction of lighter shafts and pulleys and the general adoption of belting as a mode of transmission of power.

2. The materials from which shafting is constructed and their adaptability to the purpose; giving a series of tables collected from various sources, showing the transverse and torsional strengths of the metals, steel, wrought iron, both hot and cold rolled, and cast iron. Also showing the methods by means of which these strengths are calculated.

3. The size of shafting, showing the demonstration of the general formula for the diameter of a shaft, and giving the values of the constants in those formulæ as used by different practical men. Stating the arguments for and against the use of very light shafting, and some examples of sizes which have been or are now in daily use.

The fourth general division of the subject comprises the fittings for shafts. The fittings discussed are, — Couplings; one of the first requirements that a line of shafting may run well being that the various sections shall be firmly coupled together. The requirements of a good coupling are given, and also examples of various forms in use.

Bearings; giving examples of the best forms of hangers and pillow blocks. Treating of the proper distance between two bearings, and of the metals of which they are made, and the proper pressure per square inch of bearing surface. In this connection the proper speed for shafts is spoken of.

Pulleys; the forces which act upon them; the shape and number of arms; rules for the crowning. Belting; the materials of which it is commonly manufactured, mode of fastening. The strength and the proper speed at which to run belts.

Efficiency of Marine Engines. Abstract by the author, Chas. T. Main.

The steam engine is a machine in which heat is converted into work with a certain amount of efficiency. During this conversion there are successive losses. 1. The whole of the heat from the fuel is not utilized in producing steam. 2. All the heat in the steam is not converted into work on the piston. 3. There is loss by the friction of the mechanism. The *second* and *third* factors are developed in the thesis.

1. On the different methods of using steam.

Although in some engines the expansive working of steam does not indicate a gain, yet in the modern engines the gain is worthy of notice. And the allies of the use of steam expansively are "Superheating," "The Steam Jacket," "Compounding," "High Steam Pressure" and "High Piston Speed." As a general thing now-a-days, too much expansion is attempted, and thus the results are not so economical as they ought to be. With the steam jacket and superheated steam the expansion can be carried on to a much greater extent than without, for these agents are preventions of surface condensation which is the great evil of the expansive use of steam, and the gain from their use is well worth studying. As far as the theoretical working of the steam goes, it makes no difference whether the expansion takes place in one cylinder or in a succession of cylinders; but as the size of the parts depends upon the *greatest*, and not the *mean* strain, the more expansively the steam is used the less is the *mean* pressure. Now to avoid the making of the parts so large as to increase the expense and friction, the compound engine was invented, and it has truly fulfilled the object aimed at. The parts connected with the low pressure cylinder are of more slender construction than when a single

cylinder is used. It is well known at present that high pressures, and high piston speeds are conducive to economic results.

2. On the Various Combinations of Mechanism.

The size and proportion of the engine is governed by the work which it has to perform and the instrument by which it does it. In the case of paddle wheel engines, a long piston stroke and a short arm crank on the same shaft with the wheel is conducive to speed, power, and durability. For paddle wheel engines, probably the old fashioned working beam and its connections is as satisfactory as any method of transmitting the power from the piston to the crank. It has stood the test for many years, and is now much used for river and coasting purposes. The side lever engine has been used with success for ocean steamers, but its bulk and heaviness requires it to give way to the smaller and lighter engines, such as the oscillating, the trunk, and other engines having direct connection; the oscillating engine is to be preferred to the trunk on account of its lightness, strength and durability, and its accessibility for repairs; it has come into universal favor.

But the greater economy and greater convenience of the screw vessels have caused the paddle wheel to become almost extinct for ocean and war purposes. There are various types, the most common of which are, the geared, the oscillating, the horizontal, the vertical and the inclined. The shaft of the geared engine is divided in a clumsy way, and since it is now known that high speed is economical, and for other reasons, the direct acting engine is considered as the *screw engine proper*. All the other forms have been used to good advantage, according to the purpose to which they were applied.

Whatever form is used there is a great saving by the use of the surface condenser instead of the jet condenser, and all the other details should be arranged with reference to their simplicity, durability, and access for repairs. Of course in selecting an engine judgment must be used, and attention paid to the efficiency, the location, price of fuel, etc.

In writing this thesis, the author has gathered information

from all the experiments at his command, and which he deemed sufficiently accurate to make use of. Under "Expansion" experiments of Isherwood, and those made at the U. S. Navy Yard in Boston, on the "Rush," "Dexter" and "Dallas," also those made at Baltimore on the "Bache" were referred to, and results given. Under "Superheating" those experiments made by Mr. Isherwood on the "Georgianna," "Adelaide," and "Eutaw" are given in synopsis. In studying the effect of the steam jacket, the experiments on the Brooklyn Pumping Engine, and those at the Navy Yard were referred to and results given. In determining the effect of compounding, and the gain of high steam pressure these last named were also used. A synopsis of the experiments made on the U. S. steamers "Spencer" and "McLane" to determine the relative efficiency of the screw and paddle wheel is given.

The Screw Propeller. Abstract by the author, C. F. Prichard.

Although spoken of and suggested by various authors it was not until 1836 that any extensive attempt was made to use the helicoidal or screw surface as a means of propelling vessels; then the idea was taken up in England simultaneously by Mr. F. P. Smith and Capt. John Ericsson. The exertions of either of these would have achieved a success, but the rivalry which existed hastened its introduction. Smith's form consisted of a single threaded screw of two convolutions, and was the same in principle as the true screw now in use. Ericsson's form consisted of two hoops revolving in opposite directions having short blades placed upon their circumference. The thesis contains detail drawings and descriptions of both these forms and short descriptions of numerous other forms.

The rapid rise of the propeller into general use is due principally to its power of being combined with sails, its form and the arrangement of its engine being such that it does not interfere at all with the working of the sails, while it is almost impossible to combine steam with canvas in the paddle wheel

vessel; beside this reason there are many others which are given, with contrasts between the speed of the two classes of vessels.

Under the head of the generation of the helix and helicoidal surfaces are given the definitions of, and the manner of describing and drawing the various forms of true, axially expanding, and radially expanding screw surfaces. The radially expanding, and what is called the bent back form of blade, have for their object the overcoming of the centrifugal action of the screw. A particle of water struck by a straight bladed screw is acted upon by two forces, a centrifugal force tending to drive the particle radially, and the propulsive effort resulting from the oblique action of the blade; the resultant of these two tends to drive the water from the screw in the shape of a frustrum of a cone. If this body of water could be driven aft in a cylindrical column we should utilize all the force, and to do this the blade is radially expanded or more commonly bent back. This question is discussed and a formula for the true curve deduced.

The proper form of the screw depends entirely upon slip or the recession of the water, for it is evident if there were no recession of the water we should have the case of a screw working in an immovable nut, and provided the blades were strong enough, it would make no difference whether we have one blade or four, short or long length, large or small diameter; if the pitch and number of revolutions were the same the propulsive effort would be the same; but the water does recede and hence slip must be taken into account, and it becomes necessary to choose the particular dimensions which will reduce slip to a minimum. Slip cannot be entirely done away with owing to the nature of water; the pressure of a surface against the water puts it in motion, and this motion is a measure of the resistance, accordingly although slip is an evil and occasions losses from many sources, it is a necessary one and should be regarded as a purchase of power rather than an entire loss. After discussing slip the proper dimensions of the screw are given with the reasons for choosing them, as deduced from experiments by Isherwood, Mall & Bourgois, and others.

When steam is used as an auxiliary power it is often advantageous to proceed under sail alone; in this case the screw must either be hoisted or must drag in the water. This dragging causes an important resistance, and I have given the experiments of Isherwood upon the resistance of dragging screws as determined by dynamometrical measurement.

When sailing for some time this resistance becomes a considerable amount and may be obviated by the methods of hoisting the screw out of the water; several of these methods are described and illustrated.

The two methods of making a casting of a screw, that by sweeping up a mould, and that of making a wooden pattern are described.

The principal forms of screws in use in this country are the True Screw, the Griffiths, the Hirsch and Isherwood's form; these forms are described and working drawings given, taken from actual examples now in use in the English and American Navies. The Griffiths screw is a tracing of the form of screw applied to the Great Eastern.

The Mungin and Lowe-Vansittart propellers are described, though they are used more particularly in France and England.

The resistance of a vessel is composed of Head and Skin Resistances; a method of determining this resistance is given, with the manner of finding the power of engines necessary to drive the propeller, and several methods of receiving the thrust.

DEPARTMENT OF MINING ENGINEERING.

The Port Henry Iron Industry. Abstract by the author, C. F. Allen.

Part 1. Geographical location and description of the region. Geology of the country. Discovery and development of the mines. Growth and progress of the iron industry. General situation and its advantages.

Part 2. The mines. Their number, location, history and remarks. The Cheever bed — a detail description of the mine, showing location, situation, giving manner of working, winning ore, hoisting, lighting, ventilating, materials used, drainage, pumping, timbering, tramways, inclines, surface works, machinery, railroads, sorting, dumping, labor, yield, wharves, shipment, etc. Other beds — their history and brief descriptions.

Part 3. The blast furnaces; their history and growth. The Bay State Iron Company's Furnace, with detail description of the works and working of the furnace. Statements of the amounts of different materials which go in and come out of it, and the relative proportions of charges, fluxes, ores, fuel, etc. Analyses of the ores, fuel, fire-brick, limestones used at the furnaces, and of the slag and pig produced. Table of analyses of five different pigs and the results deduced, etc. The description, in brief, of the Cedar Point Furnace.

Part 4. Comparison of this with other regions, particularly that of Lake Superior, and the cost of mining and shipping ore. Comparison of these and other furnaces. Advantages and disadvantages of the region.

Part 5. Chemical Work. Methods of analysis. Stating the method used with brief description. The reasons for so doing and results obtained.

The Metallurgical Treatment of an Argentiferous Galena from Burleigh Tunnel, Colorado. Abstract by the author, S. James, Jr.

The subject is treated as follows:

1. Position of the tunnel and purpose of working. Progress of work and number of lodes cut. Geology of the tunnel.

2. Composition (both mineral and chemical) of the ore worked.

3. Crushing, sampling and weighing of the ore.

4. Roasting. Effects of zinc blende and chemical changes the ore undergoes. Roasting furnaces. Time and coal used, and losses in lead, sulphur and silver.

5. Trial of the Flintshire process.

6. Separation of the lead from the ore by the blast furnace. Analysis of the tap cinder used for fluxingwith a calculation of slag and charging mixture. Size of blast furnace used, and the construction of the hearth. Working of the operation and blast. Tables taken of the charging and tapping. Amount of coal used. Regulating the amount of coke. Sorting and working over the products of this run to be used in a second run, or for getting the lead ready for refining. Changes before second run, new tuyeres in the furnace, and a forehearth used. Action of metal matte and slag. Tables of the charging and tapping at the second run. Separation of the lead in the forehearth, but no slag sample. Loss of lead in the whole operation and amount of fume.

7. Getting a slag sample by fusion. Manner of using a plumbago crucible.

8. Refining of lead under charcoal. Tables of the running of the furnaces, coal used, and loss of lead.

9. Sweating to get rid of copper and impurities in the lead. Description of the heater and manner of working.

10. Smelting of the copper and impurities with galena to get the copper into a matte. Time, and coal used.

11. Zincing. Parke's process. Zincing and sweating three times with one per cent. of zinc each time, by which means the amount of silver in the lead was reduced to .001 per cent.

12. Distilling off the zinc from the silver lead.

13. Cupelling. Tables of losses in the different operations.

The Richmond Blast Furnace. Abstract by the author, Thos. W. Robinson.

After a brief history of the furnace the details were considered under the following heads.

1. The Construction.

2. The Accessories and Machinery.
3. The Manner of Working.
4. The Results of Chemical Analysis.

An Investigation and Report on The Pomeroy Iron Works at West Stockbridge, Mass. Abstract by the author, Theo. E. Schwarz.

I visited the Pomeroy Iron Works last September, spending one week in studying the works and mines in the vicinity, and in collecting samples for analysis, and obtaining data for this thesis. The works consist of an anthracite blast furnace and accessories. I have considered the subject under the three following heads:—

1. The Works.
2. The Process of Manufacture.
3. The Manufacture Economically considered.

Under the first head, I have described, with drawings, the blast furnace, blast heating stove, engines, incline, etc., and the mines of brown hematite ore situated in Berkshire county, from which the furnace derives part of its ore supply.

Under the second head, I described first the process of washing the limonites, as practised in Berkshire county. The apparatus, of which I have given a drawing, consists of three revolving cylinders, through which the ore passes with water. The apparatus sizes the ore into three different products according to the sizes of the perforated plates composing the cylinders. I then described the five ores; the sampling; preparation for analysis; method of analysis, and the analyses of the ores, flux, and coal.

The following are the analyses: —

PORT HENRY MAGNETITE.		ANDREWS-BROWN HEMATITE.	
Insoluble Residue	3.54		14.16
Binoxide of Manganese	.88		.36
Alumina	1.20		1.46
Ferric oxide	90.01		73.80
Phosphoric acid	2.82		.49
Sulphur	tr.		—
Loss on Ignition	—		9.72
Lime			tr.
	98.45		99.99

CALEDONIA RED HEMATITE.		LEETE ORE ("WHITE HORSE").	
Insoluble Residue	10.57		20.80
Binoxide of Manganese	.23		2.96
Alumina	2.22		.76
Ferric oxide	72.15		56.30
Phosphoric acid	.43		.25
Loss on Ignition	8.09		16.80
Lime	4.49		
Magnesia			.42
Sulphur	—		—
	98.18		98.29

CHESHIRE BROWN HEMATITE.		LIMESTONE FLUX.	
Insoluble Residue	15.43	Silica	2.92
Binoxide of Manganese	1.13	Protoxide of Iron	.40
Phosphoric acid	2.13	Lime	42.83
Alumina	2.13	Magnesia	9.65
Ferric oxide	68.67	Carbonic acid	44.235
Loss on Ignition	10.00		
Sulphur	—		
	99.49		100.035

LEHIGH ANTHRACITE. (Very pure specimen.) The ASH contained:—

Volatile matter	11.16	Alumina	3.59
Ash	6.85	Silica	3.28
Fixed carbon	81.98	Lime	tr.
Sulphur	.0062		
	99.9962		6.87

I next gave descriptions of the operations of charging, drawing slag, casting, etc. The analysis of the slag is as follows:—

SLAG.

Silica	37.62
Alumina	12.84
Ferrous oxide	tr.
Lime	39.16
Magnesia	6.98
Protoxide of Manganese	.65
Sulphide of Calcium	2.16
Alkalies	1.11
Phosphoric acid	tr.
	100.52

The three grades of pig iron analyzed as follows: —

	I.	II.	III.
Carbon combined	.53	.585	.395
" graphitic	3.38	3.49	3.36
Phosphorus	.84	.875	
Manganese	.89	1.13	.62
Sulphur	.016	.015	
Silicon	3.24	2.16	4.44 = Silica.
Slag	20	.116	
Iron (by difference)	90.904	91.629	

Then follows a general statement and description of one week's run of the furnace, and comparative results deduced from the analyses and actual working data of the furnace.

Under this head the following points were considered: —

1. Calculation of the theoretical slag from the analyses, with its formula.
2. Calculation of formula of slag actually obtained.
3. Weight of obtained slag.
4. Calculation of amount of pig iron expected in one day, from the analyses of the ores, and comparison with amount actually obtained.
5. Composition of the most desirable slag.
6. Comparisons with other furnaces.

Under the third division of the subject, I have added up the expenses and receipts for the week ending Sept. 9th, '75, and balanced accounts, showing a loss of $ per ton of iron made. The question of greater economy of production, as affected by the ores used, has also been discussed, and whether it would be well to attempt the production of Bessemer pig. In which case, what would be advisable ores to use?

On Newburyport Silver Lead Mines. Abstract by the authors, J. H. Susmann and W. D. Townsend.

This abstract is made to embrace two theses on the same subject, which was too extensive for one person to do justice to it in the limited time.

We have given in our theses general accounts of the history, development, mineralogy, and geology of the Newburyport district; in addition to a description of the treatment by us of two ores from the Chipman lode, a rich float ore, and a poor third grade ore.

Our first experiments were on the concentration of 3d grade ore. For this purpose 1628 pounds of ore, yielding to analysis 9 per cent. of lead, .03 per cent. of silver, worth all told $18 to the ton, were taken and treated in the wet way by a system of spitzlutten, jigs, side and end bump tables, and cones. We obtained a concentration of 233 pounds, containing 73½ per cent. of all the lead, and 54.7 per cent. of all the silver in the ore, together with a slime containing 10 per cent. of all the silver. These products were both of them ready for smelting. The concentration yields to analysis 46 per cent. lead, .115 per cent. silver, worth $94 to the ton. Silver being valued at $1.15 currency and lead at 6 cents per pound.

For the metallurgical treatment we took 774 lbs. float ore, which was a little poorer than the present first class ore. It yielded to analysis 44.30 per cent. lead, .15 per cent. silver. This was treated for the lead, silver and copper by roasting, agglomerating, and subsequent smelting in the blast furnace; yielding a crude lead containing silver and some copper, and a copper matte.

As a result of the smelting, we obtained products (lead and matte), containing 234 lbs. lead, 16 oz. of silver, 0.256 oz. gold, and 5 pounds copper.

The silver and gold were subsequently extracted by Parke's process, followed by cupellation. The copper was left in the matte, from which it can be readily extracted by wet processes.

The details of this work are fully given in the theses.

DEPARTMENT OF CHEMISTRY.

Action of Tungstic Acid upon Gelatin. Abstract by the author, Wm. P. Atwood.

I have considered the subject of my thesis under the following heads:

1. Object of thesis.
2. Gelatin.
3. Tungstate of soda.
4. " acid.
5. Method of determining WI_3 and analyses of tungustate of soda.
6. Method of preparing the substance produced by the action of tungstic acid upon gelatin.
7. Properties of substance so produced.
8. Method of analysis.
9. Results of analysis.
10. Comparisons and conclusions arrived at.

On Anthracene and Associated Hydrocarbons. Abstract by the author, Chas. R. Fletcher.

This consists: —

Part 1. A digest of published papers on anthracene, anthraquinone, alizarine, phenanthrene, and their derivatives.

Part 2. Experiments made to determine the value of the various methods proposed for the quantitative determination of anthracene;

Experiments on the quantitative determination of phenanthrene.

The Action of Chloride of Sulphur upon Spirits of Turpentine. Abstract by the authors, Albert H. Low and Charles N. Waite.

The subject is treated under the following heads:

PART FIRST, BY ALBERT H. LOW.

Chapter I. 1. The action of chloride of sulphur upon certain oils, etc.

2. Extract from Parke's patent for the vulcanization of caoutchouc.

3. Treatment of the spirits of turpentine with chloride of sulphur, and separation of the products by distillation.

Chapter II. 1. Separation, purification and analysis of a substance having the composition $C_{10}H_{16}HCL$.

2. Determination of the composition and physical properties of other products.

3. Summary of the results of the investigation.

PART SECOND, BY CHARLES N. WAITE.

Chapter I. General remarks on the methods employed in obtaining the various products.

Chapter II. Purification and analysis of a sulpho compound and speculations as to its molecular structure.

Practical Estimation of the Value of Tanning Materials, together with Points on Tanning. Abstract by the author, Wm. E. Nickerson.

The work done may be divided as follows:

1. Collecting together some of the more available methods for the estimation of *tannic acid*, which have been published in foreign and American scientific works.

2. Consideration and trial of some of the more promising of these methods, by which one was found which can be used quickly, and by persons possessing but very little chemical skill. The method used, although essentially like the original, is somewhat simplified.

3. The determination of the value of various liquors from tanneries, of a number of the more common tanning materials and commercial extracts, by the selected and modified method, and the comparison of the results with those obtained by other chemists, with other methods.

4. The methods used by tanners, to test the strength of their liquors and tanning materials.

5. Investigation of the supposed loss of considerable quantities of tannic acid during tanning, by oxidation to gallic acid.

6. A partial analysis of an exhausted tan liquor.

DEPARTMENT OF METALLURGY.

A Report on the Vershire Copper Mine and Ore. Abstract by the author, R. H. Gould.

The first part of this thesis is devoted to a description of the mine and the method adopted for working the ore at Vershire. The second part describes the working of about 500 pounds of the ore at the Institute.

I. The ore mined at Vershire is a sulphide of copper and iron (Chalcopyrite) which occurs associated with a large amount of pyrrhotite and quartz. The method adopted for extracting the copper consists of the following operations. 1. Cobbing the ore to a uniform richness of about 9 per cent.; 2. Roasting the ore in large heaps to expel a portion of the sulphur; 3. Fusing the roasted ore in blast furnaces to obtain a matte containing from 30 to 35 per cent. of copper; 4. Roasting the matte in kilns to expel the remaining sulphur; 5. Fusing the roasted matte in blast furnaces to obtain pig copper containing 95 to 96 per cent. of metallic copper.

II. The working of the ore at the Institute is divided as follows:

1. Preliminary Treatment. The ore was first examined for the various minerals which it might contain. Those found were, chalcopyrite, pyrrhotite, quartz, blende, garnet, feldspar and mica. The first three make up about 95 per cent. of the ore.

The ore was next crushed to lumps of half inch diameter, and sampled. The ore on analysis gave the following:

Copper	12.18
Iron	34.93
Zinc	0.76
Lead	0.17
Sulphur	27.59
Silica	16.88
Ferric oxide	0.36
Alumina	1.90
Magnesia	1.54
Water	0.03
Undetermined	3.66
	100.00

2. Roasting of Ore. The ore was roasted in reverberatory furnaces for four hours, during which it lost over one half of its sulphur.

3. Fusion for Matte. The roasted ore was fused in a blast furnace, puddle cinder and limestone being used for fluxes.

The main products were, a matte containing about 25 per cent. of copper, and a perfectly fusible slag of the following composition:—

CuO,	0.56
PbO,	0.29
SiO_2,	35.97
FeO	41.90
$Ab_2O_3 + P_2O_5$,	8.55
CaO,	8.56
MgO,	1.14
Undetermined,	3.03
	100.00

4. Roasting of Matte. The matte was roasted in four charges, of 56 lbs. each, for about six hours.

5. Fusion for Black Copper. The roasted matte was fused in a blast furnace. Revere acid slag and sand being used as fluxes. The main products were:

1. Black Copper very highly charged with iron;

2. Matte containing about 44 per cent. of copper;

3. Slag which was perfectly fusible, and on analysis was found to contain no copper.

DEPARTMENT OF NATURAL HISTORY.

Catalogue of the Alcidæ in the Museum of the Boston Society of Natural History; with a review and proposed classification of the family. Abstract by the author, W. B. Barrows.

In this paper the family is first located and then briefly defined; its prominent characteristics, as shown in the various specimens in the Museum, being simply enumerated, and the more critical notice of specific and generic differences left for the descriptions of Genera and Species which immediately follow.

The descriptions are all original and are made from actual specimens in the Museum. Twenty-one species are included in the family and twelve of these, representing every Genus, are contained in the Museum. No descriptions of species have been given where actual specimens have not been handled, but each species is assigned its place in such a manner as to make a connected series which seems to best represent the natural relations of the members. One feature of the work is the reduction in the number of Genera usually admitted, only seven being here accepted; while the exclusion of sub-families is a parallel feature. These two points, involving the whole relation of species to species, are somewhat fully, though not exhaustively, discussed in the concluding third of the paper, where the grounds for every step have been carefully considered.

Two plates, containing figures of thirty beaks (both plan and elevation) conclude the paper.

The whole classification differs widely from those most generally in use; but the writer has been largely guided by such facts in the embryology of the group as have been within his reach and ability; and these facts, which have thus far been too generally overlooked, have made many of these changes imperative.

Geology of Eastern Massachusetts. Abstract by the author, W. O. Crosby.

This essay is prefaced by some remarks on the general structural features of the eastern United States.

Attention is called to the existence, during Paleozoic time, of a great gulf on the western side of the Appalachians, forming part of the interior Continental sea.

In this Paleozoic gulf is found a probable cause for the greater thickness of the Paleôzoic sediments in the Pennsylvania region as compared with any other part of the Continental basin.

The general absence of Paleozoic strata from the Atlantic slopes of the Appalachians is noted, and the fact pointed out that the Paleozoic rocks of eastern North America were deposited about the western and northern sides of what is now a long and narrow belt of land stretching from Maine to Georgia. Much evidence is adduced to show that this limited area had a greater extension to the east and south-east in ancient times than now; that there must have been during Paleozoic time, where now lies the basin of the Atlantic thousands of fathoms deep, a great continent, from which were derived the detrital materials forming the Paleozoic sediments of both Europe and America.

It is shown that our Atlantic coast line exhibits two grand deflections or bays, — the Gulf of Maine lying between Cape Cod and Nova Scotia and the large nameless deflection of the middle portion of the coast between Cape Cod and Cape Hatteras. The latter, which has been christened the Alleghanian Gulf, is proved to date from the beginning of Mesozoic time and to owe its existence to the great accumulation of sediments forming the Alleghany Mts.

The Gulf of Maine, on the contrary, is shown to be far older, having been, like the Gulf of St. Lawrence, with which it formerly communicated, in existence during the whole of Paleozoic time. Its origin is found in the erosion of an anticlinal of old crystalline rocks.

The age and relations to the Paleozoic sediments on the west and the Metazoic on the east of the rocks forming the long and narrow belt of land, before adverted to, stretching from Maine to Georgia, are discussed at some length, shown to be, with small exceptions, chiefly crystallines, and to probably ante-date in their origin the earliest Primordial.

Coming to the proper subject of the paper, the relations of Massachusetts to this Eozoic belt are defined and the rocks of the State divided into two principal groups: (1) the crystalline, and (2) the uncrystalline.

The crystallines are further divided into the Norian, the Huronian and the Mont Alban. Then follows at considerable length, forming the major part of the essay, an account of the lithology, distribution and probable origin of the various rocks forming each of these formations.

The rocks referred to the Norian are identified with the Norian of other regions, and, although occupying but a small area in the Eastern part of the State, are shown to be of great scientific importance, since they are the oldest rocks in Massachusetts and perhaps in New England, and afford a key to the geology of this whole region.

The stratigraphical relations of the Norian of this vicinity to the rocks of the same and of Laurentian Age in New Brunswick is pointed out.

The rocks of the Huronian Age are divided lithologically and chronologically into several groups, which, stated in their order of sequence, are granite, felsite, diorite, and stratified rocks including limestone. These are minutely described, their lithological and stratigraphical relations pointed out, showing that they are strictly members of one and the same series, and the law governing their distribution indicated.

The derivation of the compact felsite from conglomerate is briefly treated, old views discussed and new ones advanced.

General sections across this formation from north to south are given, showing that there is a repetition of the strata which can be accounted for only by a gigantic fault which must ex-

tend from the shore in Ipswich south-westerly through Essex and Middlesex counties. It is conceived to die out near Westborough, and a reason is found here for the existence of the peculiar band of Huronian rocks extending south-west from Concord and piercing the Mont Alban formation.

The existence of many minor faults is rendered probable, and it is proved that the diorite area of Salem, Swampscot and Marblehead has been thrown down thousands of feet by a great fault which brought up the Norian rocks of Salem.

The Mont Alban formation is treated in a similar manner, but with less detail. The rocks of this age are shown to form, like those of the Huronian period, a complete chemical and lithological series, a rounded cycle of sedimentation.

Particular attention is given to the distribution and stratigraphical relations of the rocks of the Nashua and Merrimac valleys; and general sections across these valleys are given which show that the peculiar relations of the rocks are due to faults never before noticed.

The Mont Alban rocks are found, in their general distribution, to lie concentrically about the Huronian as the Huronian do about the Norian; and it is pointed out that these formations sustain precisely the same inter-relations in Maine, New Brunswick and Nova Scotia that they do in Massachusetts.

In this manner is established the existence of the great Eozoic Anticlinal, the erosion of which produced the gulf of Maine. The occurrence of Primordial and later sediments at various points in the Gulf of Maine, is appealed to as evidence that the erosion of this Anticlinal was completed before the beginning of Paleozoic time. Preceding the systematic account of the Palezoic rocks, two general sections are introduced showing the probable form of the valleys in which they were deposited.

The slates in the vicinity of Boston are chiefly referred to the Acadian period, while the great mass of the conglomerates is regarded as synchronous with the Carboniferous conglomerates of Bristol County and Rhode Island, which they closely resemble.

The conglomerates and sandstones forming the Norfolk county belt are referred, on stratigraphical grounds, to the Devonian Age.

The paper is concluded by an account of the disturbance closing Paleozoic time, wherein is traced the origin of many of the more prominent geological and topographical features of this region.

DEPARTMENT OF PHYSICS.

On the Mean Specific Gravity of the Earth. Abstract by the author, J. B. Henck, Jr.

1. General principle of all methods of finding the mean specific gravity of the earth.

2. First hint of an actual experiment by Sir Isaac Newton.

3. First actual attempt to determine the deviation of the plumb-line by the attraction of a mountain, as suggested by Newton, made by Bougner and others in 1738.

4. Maskelyne's experiments in 1774, Hutton's calculation of the results, and subsequent lithological survey of the ground by Playfair, with remarks on the use of the terms "quantity of matter" and "density."

5. Experiments by Col. James in 1856.

6. Experiments by Airy in 1826, 1828, and 1856.

7. Experiments by Pierce in 1874.

8. A second class of experiments, to be performed in the laboratory.

9. First experiments of this class, by Cavendish in 1797–98.

10. Experiments by Reich in 1837.

11. Experiments by Baily in the same and following years.

12. Second series of experiments by Reich in 1852.

13. Experiments by Cornu in 1873–74.

14. My own attempted experiments the past season.

15. Recapitulation of results.

16. References.

There are several sketches in the text, and a photograph of my own apparatus.

The Atomic Theory as Applied to Gases; with Some Experiments on the Viscosity of Air. Abstract by the author, Silas W. Holman.

This thesis is a result of a study of the "Atomic Theory" of the constitution of matter, especially in its application to the explanation of the phenomena of gases. A review of the theory, from its rise in the speculations of Democritus and others more than five centuries before the Christian era, to the most recent development in its application to the phenomena of gases by Clausius, Maxwell and many more, has been outlined in the first portion of the paper. The methods of application of the hypothesis of a gas made up of rapidly moving particles to the explanation of the relation between the pressure, temperature and density of a gas is next considered. This leads to a comparison of the results obtained by different investigators from the time of Boyle (1650) to the present. Such a comparison shows the uncertainty which still remains as to the nature of the derivation of gases from the law of Mariotte, and the desirability of a more thorough discussion of all the results yet obtained, as well as the need of more accurate observations at high pressures.

Another class of the phenomena exhibited by gases, namely, those due to their viscosity or internal friction, is one quite well adapted to test the conformity of theoretical deductions with the results of experiment. From the hypothesis of perfectly elastic spherical molecules (or their equivalents) acting upon each other by impact after moving over a rectilinear path, Maxwell has deduced the law that the viscosity of a gas is independent of the pressure upon it and increases proportionately to the 0.5 power of the absolute temperature. The experiments of Meyer, Maxwell, Puluj and von Obermayer on dry air have given, instead of 0.5, values of 0.75, 1.0, 0.66 and 0.75 respectively. These various results are discussed by a special application of the graphical method which shows a great discordance in the case especially of Meyer's extensive investi-

gations. These give in fact almost all values of the power from a negative one to +2.3, which shows that they entirely fail, even when their best values are selected, to establish any law for this variation. Maxwell's published results seem insufficient. Those of Puluj are more concordant. Only the conclusions of von Obermayer as published in a short notice have yet been attainable.

The apparatus which I have used in my experiments in the Physical Laboratory is dependent upon the law of Poiseuille as applied to the transpiration of gases through capillary tubes. This law is based upon the assumption that the viscosity of a gas is independent of the pressure upon it; a law which I consider as verified for variations not exceeding two or three atmospheres by the experiments of Graham, Meyer, and Maxwell. In this apparatus the same volume of gas is transpired successively through two capillaries of glass into a receiver continuously exhausted by means of a Richards' aspirator. The pressure of the gas at the entrance and exit of each tube is measured by means of two mercury gauges and a barometer. The capillaries may be at the same or at different temperatures. From the reading of the gauges when both are at the same temperature the constants of the apparatus may be determined, which must undergo a slight correction for variations of temperature since they depend on the dimensions of the capillaries. When the tubes are at different temperatures, the effect shows itself in the guage readings. From these and the previously determined constants, the effect of the known variation of temperature upon the viscosity is determined. The errors of measurements of volumes of air are thus eliminated, and the accuracy of the results depends only upon the measurements of temperatures and columns of mercury. As a mean of nine measurements I get the power 0.770, the extremes being 0.738 and 0.782. The greatest variation obtained with the apparatus was in the value 0.881 which was one of two observations rejected at the time of making. This form of apparatus does not furnish absolute values of the coefficient of viscosity, but may

be readily extended to accomplish this by measuring the volume of gas transpired in a certain time. The superior concordance of these preliminary results warrants the expectation of absolute values surpassing in accuracy those of previous investigations.

The deviation of all experimental data upon this law from the theoretical value of the 0.5 power of the temperature indicates, probably, a false hypothesis with regard to the mode of action of the molecules at impact. Maxwell has reinvestigated this subject upon the hypothesis of a repulsive force between the particles varying inversely as the fifth power of the distance, which makes the viscosity proportional to the first power of the absolute temperature. This is probably not the law however, and it would seem that it would be necessary to establish the experimental law with certainty before giving ourselves to any theoretical deductions from it.

New Experiments in Sound. Abstract by the author, William W. Jacques.

The experiments consisted of three series. The first was made for the purpose of testing the law of inverse squares; the second to show that the principles of Fresnel and Huyghens, announced for the ether waves, could be applied to waves of sound; and the third, for the purpose of measuring the velocity of sounds of considerable intensity.

First Series — There is every dynamical reason for believing that the intensities of light, heat and sound diminish as the reciprocals of the squares of the distances from their origins. That this is true of light and heat has been demonstrated experimentally. The case of sound, however, has hitherto received no experimental demonstration. The following experiments furnish us with a proof of this law for the case of sound.

If two resonators be placed equally distant from an organ pipe, and connected by tubes with two prongs of a forked tube in such a way that the waves from the two resonators shall

arrive at the fork in opposite phase, they will neutralize each other, and if the stem of the fork be connected with the ear no sound will be heard.

If, for one of the resonators, we substitute a pair, we may, by moving the single resonator nearer to the organ pipes and properly changing the length of its tube produce the same complete interference. If the law of inverse squares holds good, the distances of the single resonator and the pair from the pipe should be as one to the square root of two.

The observed and calculated results agree almost exactly, so that we are now warranted in assuming the law for sound on as valid experimental grounds as for light and heat.

Second Series — There seems to be no *à priori* reason why the principles of Fresnel and Huyghens should not be applied to our atmosphere. The following experiments on the diffraction of sound show that they may be so applied. It is well known that when light, diverging from a centre, passes by a sharp edge, an interference is produced, so that, if a screen be placed just behind the edge, we shall see upon it alternate light and dark bands. The experiments which we have made in sound are analogous to these. In the path of rays of sound diverging from an organ pipe, an edge, consisting merely of a wide board, was interposed. In the rear of this edge alternate bands of maximum and minimum intensity of sound were observed, corresponding, in their positions, to the theoretical bands calculated by formulæ essentially similar to those used in the case of light.

From the data furnished by these experiments, we may calculate the length of a sound wave, the velocity of sound, and, in short, all of the quantities dependent upon the velocity of sound, as well as acoustic quantities analagous to the optical quantities deduced from the diffraction of light.

Third Series — Many eminent mathematicians and physicists have raised questions as to whether the velocity of sound is not affected by its intensity and pitch, by barometric pressure, hygrometric state and by other supposed causes. The follow-

ing experiments, which form one of several series being made for the settlement of these questions, have for their object the measurement of the velocity of sound near to the mouth of the cannon. If the velocity varies with intensity, these results should be larger than those obtained by other methods.

The method consists of an automatic measurement of the velocity between the members of a series of membranes, placed at different distances from the source of sound, by causing the sound, as it passes each membrane, to register its passage, by means of suitable electric connections, on a chronograph.

By the kindness of Colonel Laidley, commander of Watertown Arsenal, the experiments were carried on at that place.

The gun used was a six-pounder. From the mouth of the gun a series of three membranes was set up at intervals of thirty feet. These membranes were made of thin rubber stretched over a hoop nine inches in diameter. To the centre of the membrane was attached a polished brass shelf, upon which rested a polished steel spring. The shelf was connected with one wire, and the steel with the other running to the chronograph. When the spring rests upon the shelf it completes a circuit, which is the primary coil of an inductorium. The passage of the sound wave by a membrane breaks this circuit, and so causes a spark to pass between the terminals of the the secondary coil of the inductorium. The chronograph used was a Schultz, which consists essentially of a rapidly revolving polished silver cylinder, upon the lampblacked surface of which a tuning fork is allowed to draw its curve, and so to furnish a scale of times. One terminal of the inductorium is led to near the cylinder through a glass tube; the cylinder itself forms the other terminal. The breaking of the primary circuit at the membranes, then, causes a spark to pass from the wire to the cylinder, which is registered by a dot in the lampblack. An arrangement was attached to each of the membranes, by means of which the current, after being broken at it, could be sent through the next one before the sound wave arrived at it. The experiments which have been made show that the velocity of

sound in the vicinity of a gun is greater than at a distance by several feet. This is in accordance with theory. The method will, probably, when perfected, furnish the most accurate results of the velocity of sound yet obtained.

There is also a chapter describing some experiments made in a section of the new Sudbury River Conduit to test the effect of a very great variation of pitch upon the velocity of sound; and a final chapter describing a method to be used in the study of the effects of barometric pressure and hygrometric state of the atmosphere on the velocity of sound.

DEPARTMENT OF SCIENCE AND LITERATURE,

Australian Colonies of Great Britain. Abstract by the author, Chas. A. Sawyer.

Under the above title are included the following: New South Wales, Victoria, Tasmania, New Zealand, Queensland, South Australia, Western Australia, Fiji Islands.

Occupying, as they do, a position second only in importance to that of India, the colonies of Great Britain in Australasia demand something more than a merely general treatment as a group. In this thesis therefore I have entered somewhat into the details of each colony in its relation to the others of the group, paying also particular attention to their relations, commercial and political, with the mother country, and not only as a group but individually. In order to do this to better advantage and to systematize the treatment of the subject as much as possible, I have divided it into two parts as follows. In the first part I have briefly sketched the general and more important points in connection with the early discovery and history of Australia, this being common to all the colonies of the group, New Zealand alone excepted; I have also indicated their present relative positions as regards commerce, industry, and general prosperity, and verified my statements as far as possible by means of statistics and quotations from books and papers of au-

thentic publication. This part of the subject is treated under the following heads: History and Discovery; Climate and Physical Features; the Natives; Government, including the colonial system of land tenures; Trade, Commerce and Industry. In the preparation of the pages devoted to this first part the following authorities were consulted:

"Australia and New Zealand," (3 Vols.), by A. Trollope.

"Australia," by Wm. Westgarth.

"Discovery and Exploration of Australia," (2 Vols.), by Rev. J. E. T. Woods.

"Life and Growth of Language," by Whitney.

"Queensland, Australia," by Rev. J. D. Lang.

"Colonial Constitutions," by Sir Edwd. Creasy.

Stateman's Year Book (1876), by Martin.

Edinburgh Review (1865).

In the second part I have taken up the colonies separately in the order of their commercial importance, and entered into a more detailed account of each and with special reference to its commercial relations with others of the group and Great Britain.

New South Wales, though at present occupying a second place in the list as thus arranged, is the oldest and parent colony of all those that have grown up about her, and for this reason therefore I have given her the preference to Victoria in the order of their treatment. Comparisons of the colonies have been made, under the different heads into which the treatment of each is divided, in order better to show the kinds of industry, agricultural, pastoral or manufacturing, characteristic of it, and to which the natural resources of each seem best adapted. The divisions under each colony are as follows:

Area; Discovery and History; Climate; Geology and Mining; Natural History; Laws and Government; Population; Education and Religion; Revenue and Expenditure; Trade and Commerce; General Items. The same scheme is not followed in the treatment of each colony, however, though varying but slightly throughout the list, one topic being necessarily in-

cluded perhaps in another and not requiring a separate discussion or admitting of it in some cases.

Statistics have been given the preference to more interesting facts in connection with the history and present condition of the colonies, of which many have been reluctantly passed over and omitted. More space has been devoted to Victoria as the most important, and less space to Western Australia as the least important, of the colonies of the group.

The authorities referred to in this division of the subject include those already mentioned together with the following: Accounts and Papers of the Colonial Government, 1852–3; Greater Britain, by C. W. Dilke; What we saw in Australia (1875); The colony of Victoria, by Wm. Westgarth; Victoria and Tasmania by Trollope; Dublin Univ. Magazine, Jan. 1876; Journal of the Statistical Society, Dec. 1875; Goldfields of Victoria, by R. Brough Smith; Victoria and the Australian Gold mines, by Westgarth.

DEPARTMENT OF PHILOSOPHY.

Concerning Kant's Transcendental Æsthetic. Abstract by the author, D. W. Phipps.

I.

EXPOSITION OF KANT'S IDEA OF A CRITIQUE OF THE PURE REASON.

1. Mutually independent Mind and Thing assumed.

2. The assumed hypothesis (to be proved) that the qualities of the object pertain only to the Mind.

3. In consequence of the assumed duality of Mind and Thing; together with the apparent element of universality in experience, the theory arises that

(*a*). There are two sources of knowledge, viz., Sense and Understanding.

(*b*). And hence the problen of the Critique: How are synthetical judgments possible *a priori*?

4. The Sense-cognition, as distinguished from the cognition of the Understanding, has an element which is contributed by the spontaneity of the Mind; hence,

5. The necessity of a Transcendental Æsthetic; which is a critique of the spontaneity in the sense-object, as distinguished from the spontaneity of the Understanding; the critique of the latter being named Transcendental Logic.

6. What we shall expect Kant to prove in the Æsthetic, in view of the foregoing notion of its purpose.

II.

REMARKS CONCERNING THE PLAN OF THE ÆSTHETIC; AND NOTICE OF SOME OF ITS DEFECTS.

III.

AN ATTEMPT TO RESTATE THE ÆSTHETIC SO AS TO AVOID SOME OF THE NOTICED DEFECTS.

1. *Definitions:* Sense; Intuitions: pure, empirical, external and internal; Phenomenon; Sensation, Space and Time; Matter, Form.

2. The Æsthetic a critique of Space and Time.

(*a*). Space and Time to be explained Metaphysically and Transcendentally.

3. *Metaphysical Exposition:*

(*a*). What a Metaphysical exposition is.

(*b*). Space and Time are not general concepts.

(*c*). They are not concepts of any sort; and as an intuition can be given by a single object only, so Space and Time are like intuitions, for they are each only one.

(*d*). Space and Time give rise to synthetical propositions *a priori*; but a conception contains only a unity of certain marks or characteristics, which may be discovered by analysis, and does not contain anything beyond those marks; hence a conception cannot give synthetical propositions *a priori*; hence Space and Time are not conceptions; hence they must be intuitions.

4. *Transcendental Exposition:*

(*a*). What a transcendental exposition is.

(*b*). What "transcendental" means.

(*c*). An object cannot be cognized as extended and enduring unless there be the representation *a priori* of Space and Time, in which the object may extend or endure.

5. The exposition of Space as a representation *a priori*, makes possible the conception of mathematics as a synthetical science *a priori*. And motion, the change of place of an extended object in Time, can be understood, and explained *a priori*, only on the ground of the representation *a priori* of Space and Time.

6. *Conclusions:*

(*a*). Space and Time are subjective, only, but universal.

(*b*). Sensation is subjective, only, but singular.

7. *Elucidation:*

(*a*). Change is real for us.

(*b*). Space and Time are only elements of a Transcendental Æsthetic.

8. The bearing of the completed Æsthetic upon the solution of the main question: How are synthetical judgments possible *a priori*?

IV.

QUERIES.

1. How did Kant discover that the Sense-object was *occasioned* by the thing-in-itself?

2. Has he proved that Space and Time are *a priori;* that is, universal and necessary, but independent of sensation?

3. Has he proved that Space and Time are intuitions?

4. If Space and Time are independent knowledge of *one* sort, and Sensation is independent knowledge of *another* sort, how can the two sorts be united?

5. Is the so-called *a priori* from the *human* reason or from *Reason*? that is, do we not know the Absolute?

6. Has Kant's theory of cognition provided for Transcendental reflection?

Historical and Logical Relations between Fichte and Kant. Abstract by the author, R. C. Ware.

Fichte's adoption of the philosophic standpoint of the absolute validity of reason, through his researches in theology. His adoption of a fatalistic determinism. His subsequent conviction of the freedom of the will by Kant's new theory that the nature of liberty is subjective. Fitche's hearty acceptance of Kant's doctrine. Fitche's visit to Kant. The "Critique of all Revelation," an application of the "Critical" Principle. Development of Fichtianism by reflection on the contradiction of Kant. Development of the theory of intellectual intuition by reflection on the implications of the "Transcendental Logic." Derivation of the Ego as ground of the universe, and of the one fundamental principle of thought (the Principle of Identity), from Kant's "Synthetical Unity of Apperception." Development of Fichte's theory that will is a necessary part of real thought, out of the adoption of Kant's practical philosophy. The real character of the revolution wrought by Kant in philosophy.

THE RUSSIAN SYSTEM OF SHOP WORK INSTRUCTION.

To the Corporation of the Mass. Institute of Technology:

GENTLEMEN: — It must be admitted that technological education is still in the experimental state. The methods in use, even in our primary schools, do not pass unquestioned, and upon the best methods of teaching the ancient languages, and the pure mathematics, subjects which have constituted the main elements in all high and generous culture for ages, the most learned doctors disagree. We could hardly expect, then, that the best methods of teaching the modern sciences should already have been found; and particularly the best way of working them out practically in the industrial arts. Ten years ago, when the courses in this Institute began, some valuable experience in teaching science had been gained. It had been found that simple text-book instruction in Chemistry, unaccompanied by corresponding laboratory work by the pupil, was comparatively useless; that a small professional laboratory, while good for an advanced specialist, was no place for a beginner; and, in short, it was too expensive to teach each pupil singly. Hence there had grown up, as a necessity, large and well arranged laboratories, especially adapted to the instruction of pupils in as large classes or sections as one or more teachers could instruct well at the same time. This step of teaching laboratory work to large classes of pupils, and all in about the same state of progress, was found to be most economical for both parties, and the only system by which this element of instruction could be maintained with a large number of pupils. It has also been found by experience that general chemistry, quantitative and qualitative analysis, and the various departments of

applied chemistry, can best be taught in laboratories adapted to each. Such are the steps which have been taught us by experience in a single department. But unfortunately, in hardly another department have we the same experience, and an equally well defined and systematic method of instruction. In architecture, in laboratory instruction in physics as a part of the required course of each candidate for a degree, in the mining and metallurgical laboratories for the working of ores in quantities, and in the laboratory for teaching the nature and use of steam, this Institute has the honor of having led the way. But in these cases each year's experience serves to suggest improvements in details, which add materially to the amount and quality of the work done.

While we have been gaining experience in these directions, other technical schools have also been working out, more or less fully, other phases of the same great educational problem upon which we are all engaged; each doing its work under such limitations and conditions, and in such main directions, as its location and other controlling circumstances have dictated. Each, therefore, owing to a great extent to these varying circumstances and conditions, has its lesson to teach to all the others; and it was with the expectation that the opportunity of learning some of these lessons would offer, that our Professors and Students made their recent visit to the International Centennial Exhibition at Philadelphia.

The Act of Congress of 1862, giving lands to the States for educational purposes, while not excluding other subjects, laid particular stress upon the two great industries upon which the well-being of any great community must always mainly depend, agriculture and the mechanic arts. While all the sciences having a direct application to these arts should be taught, there can be no doubt that it was also the intention that the arts themselves should be taught in the most practical and fundamental way; and accordingly, we find farms in several of the States, used in one or two cases, simply as experimental stations, but in most cases conducted as model farms, and depending to a considerable extent upon the labor of the student, which is regarded as instruction, and is made a required part of the curriculum of the course in agriculture.

In like manner many of these schools have already established shops for the instruction of their students in the mechanic arts.

As this Institute was selected by the State to represent the mechanic arts, for which we receive one-third of the income derived from the national grant, we have watched the experiments in this department, which the various schools have been making with the deepest interest; believing, that the time would come, when the best solution would be reached, and trusting that when it was reached we should be in a condition to take advantage of the experience. In the meantime the steam laboratory is all we have been able to furnish of a practical character to our students in mechanical engineering, beyond what could be gained by a good locality for manufacturing, and the particular kindness of the directors.

We went to Philadelphia, therefore, earnestly seeking for light in this as well as in all other directions, and this special report is now made to ask your attention to a fundamental, and, as I think, complete solution of this most important problem of practical mechanism for engineers. The question is simply this — Can a system of shop-work instruction be devised of sufficient range and quality, which will not consume more time than ought to be spared from the indispensable studies?

This question has been answered triumphantly in the affirmative, and the answer comes from Russia. It gives me the greatest pleasure to call your attention to the exhibit made by the Imperial Technical Schools of St. Petersburg and Moscow, consisting entirely of collections of tools, and samples of shop-work by students, illustrating the system which has made these magnificent results possible.

In all constructions a certain limited number of typical forms are found, these forms being more or less modified, to adapt them to special constructions. These forms will also fall into groups each to be worked out in a certain way and with special tools. If, then, the student can be taught to work out these forms, each in the best way, and with the tools best adapted to the work, he will be far advanced in the skill which will make him available and useful in construction. The ideas involved in the system are, first, to entirely separate the *instruction* shops from the *construction*

shops; second, to do each kind of work in its own shop; third, to equip each shop with as many places and sets of tools, and thus accommodate as many pupils, as a teacher can instruct at the same time; and fourth, to graduate the samples to be made in each shop according to some scale, that of difficulty being probably the best in practice. In short, in these preliminary instruction shops, the *arts*, which find their applications in construction, are systematically taught.

It will be seen, then, that the problem thus far is simply one of systematic instruction, given by an expert in each shop, and having the same end in view as instruction in any other subject or department. The aim is to give sufficient skill in each specialty in the shortest possible time, and to give the instruction to as many at the same time as the teacher can well instruct, thus securing the greatest economy of time, and therefore money, to both teacher and pupil. After the student has finished his course in the several instruction shops, he may then be transferred to a construction shop, which may still be used simply for instruction as in the St. Petersburg school, no orders being taken, and all constructions being made simply to give variety to the instruction; the machines and tools made being sold at the end of the year if wanted.

Or he may be transferred to a construction shop, which takes orders and depends largely upon the work of the pupils, as at the Moscow school, the construction shops being in each case owned and controlled by the school.

With this preliminary exposition, I propose now to ask your attention to details, mainly in connection with the statements which these schools make in explanation of their exhibits at Philadelphia.

And first, the statement of the St. Petersburg school:

"The Practical Technological Institute of St. Petersburg is one of the highest technical schools now existing in Russia, and has capacity for five hundred students. It is divided into two departments; Mechanical and Chemical.

The Mechanical Department prepares technical men for the management of mechanical work-shops, and of the rolling stock on railroads. Owing to this the Mechanical Department is divided

into two special sections; one of them graduates engineers for the workshops, and the other for the railroads.

Before entering the Institute as student the young man must be graduated in one of the middle schools (gymnasiums), and must undergo a competitive examination.

The whole course of instruction in each department of the Institute is arranged for five years, and is divided into five yearly courses.

In the Mechanical Department the course of instruction includes: Mathematical analysis, natural philosophy, theoretical and practical mechanics, mechanical technology, the art of construction, and the art of mechanical drawing. Besides this, a part of the time is employed by the students in manual labor in various workshops and mills belonging to the Institute.

During the full five years of the course of studies, six hundred and forty-eight hours are devoted to the manual labor in workshops. There the students, under the management of experienced masters, begin to exercise in the most simple works, gradually passing to more complicated, and at last finishing with construction and joining of all the parts of an engine.

The collection of practical works exhibited in the Machinery Hall by the Institute is composed of articles manufactured by the students during the year 1875, and represents the systematical course of practical studies adopted by the Institute.

The system introduced with this purpose is as follows: The practical studies are divided into three courses; for the first course each student is induced to work with a chisel and file upon the cast-iron, performing six consecutive tasks exhibited under the No. I. of the collection.

For the second course the students begin by working upon wrought-iron, fulfilling nineteen consecutive tasks represented under the No. II. of the collections. Thereafter they are removed to the fitting shops, where they are obliged to perform fifteen tasks, exhibited under the No. III. of the collection, occupying themselves with turning, cutting screw-threads and soldering.

The last course is intended for the construction and joining of different engines. The samples of machine tools built by the students of this course are exhibited under the No. IV. of the collection."

I am indebted to Dr. August Peters, Mechanical Engineer, and Director of the shops of this school, for the following details: The filer's shop, N°. I, has about sixty places, each fitted with a vise, and the tools necessary to do the work of the course. The forging shop, No. II, is fitted with ten places, and the turning shop,

No. III, with sixteen places, the students working in these shops in alternating sections. The lathes are all run by the foot, and the only power used in any of these instruction shops is for the blast in the forging shop, which each student takes from the main pipe. Even here power could easily be dispensed with by attaching a hand blast to each forge. The shop work, which, it will be noticed, takes but six hundred and forty-eight hours for the four courses, is obligatory, and graduates are able to construct their own designs with their own hands.

The quality and variety of the work exhibited, and all done by the students during the year 1875, furnish the very highest evidence of the value and entire success of the system.

And second, I beg you to particularly notice the able and instructive presentation of this important subject by Victor Della-Voss, Director of the Imperial Technical School of Moscow, together with a brief preliminary statement of the general features of the school. I am indebted to Professors Aeschlimann and Petroff, the gentlemen in charge of this exhibit, for polite attentions.

"The Imperial Technical School of Moscow is a high class Special School, principally intended for the education of Mechanical Constructers, Mechanical Engineers and Technical Engineers.

The School consists of two divisions, general and special, each of which has a course of three years. The special division is divided into three branches: Mechanical Construction, Mechanical Engineering and Technological Engineering.

The three years' course of the general division embraces the following subjects: Religion, Free Hand and Linear Drawing, Descriptive Geometry, General Physics, Zoology, Botany, Mineralogy, Chemistry, Geodesy, Analytical Geometry, Higher Algebra, Differential and Integral Calculus, General Mechanics, Drawing of Machine-parts, the French and German Languages, *i. e.*, all Scientific subjects, the previous knowledge of which is required from the pupils of all the three following branches.

In the special department, the three years' course of the three branches contains the following subjects: Organic and Analytical Chemistry, Metallurgy, Practical Physics, Mechanical and Chemical Technology, Technics of Wood and Metals, Analytical Mechanics, Construction of Machines, Practical Mechanics, Railway Construction, Engineering and Constructive Art, Projecting and Estimating of Machines, Works and Mills, Industrial Statistics, and Book-keeping.

Every one of the appointed sciences is taught fully, or in a condensed form, according as it is considered a fundamental or collateral subject of the given branch. The students of all the classes are occupied during a stated time in practical work in the laboratories and mechanical workshops.

The School has also a preparatory division, of three classes, with the same curriculum as the higher classes of commercial schools, and is intended for such pupils as, by any reason whatever, have not been enabled to pass through the full course of the commercial or of the classical schools.

Admission into the School as boarder or day scholar is obtained by competitive examination, in accordance with the ordained programme.

Pupils who have passed through the full school course of the Gymnasiums may be admitted without further examination to the lectures of the second general class of the School, but pupils of the last class of the Gymnasiums, who have not passed their final examination, are admitted only to the first general class of the School.

The pupils wear the appointed half-military uniform.

Pupils who have obtained in the school the appointed grades, receive acknowledged rights in the service of the government.

The School is maintained by funds from the following sources: percentage on funded capital,[1] fees of private boarders and foreign hearers, and profits received from the Mechanical Works.

The annual receipts of the School amount to 160,000 dollars.
" " expenses " " " " 140,000 "

The Technical School is under the immediate patronage of *Their Imperial Majesties.*

Auxiliaries to Instruction. The School possesses a special library, containing more than six thousand volumes of works on specialties, a cabinet of physics, two chemical laboratories, a cabinet of mechanical models, a cabinet of natural history, extensive mechanical works with separate smithy and foundry, and also school work-shops.

Almost the whole of the collections exhibited by the School at the exhibition at Philadelphia, are immediately connected with the school workshops, and we shall therefore endeavor to give a few details concerning the latter.

No one will deny that a close acquaintance with hand labor, and, in general, practical experience in mechanical works, are matters of the utmost importance to every engineer.[2] The drawings of an engineer thus trained will always be distinguished by solidity and that practical judgment, which is the result not only of the study of scientific truths, but also of the acquirement of a

[1] The School capital amounts to about 2,030,000 dollars.
[2] We speak here of Mechanical Engineers and Constructers.

certain familiarity in their application to practice. That the knowledge of hand labor is of extreme importance to a young man devoting himself to technical activity, and that it is considered an absolute necessity to him, we are convinced by the circumstance that the greater number of the polytechnical schools of western Europe demand from the students who enter them either a previous stay, of a certain duration, at some works of industry, or issue to them a diploma, attesting their accomplishment of the course, after they are in position to show that they have been occupied practically for a definite period at some such works on their leaving the school.

If we contemplate the matter itself more profoundly, and acquaint ourselves more closely with the circumstances of the practician at private works and mills, we must, disregarding exceptional cases, since it is not those which form the rule, arrive at the sad conclusion that a young man, desiring to acquire practical experience in a short time, and without the aid of an experienced guide, loses, at private works, nine-tenths of his whole time entirely unprofitably. As we are at present addressing persons well acquainted with this matter, we do not consider it necessary to bring forward arguments in support of our statement. The practical information, acquired in works by a young man before entering a polytechnical school, is very inconsiderable, and therefore does not possess the desired significance.

Such information is, on account of its defectiveness, of little assistance in promoting the study at school of Practical Mechanics, the construction of machines or the drawing up of plans and estimates for mills and works.

A young man on leaving a polytechnical school should endeavor to carry on his practical education; should fix upon some mill or works in which, being, in the majority of cases, of course, left to his own initiative, he may find place and opportunity for his further self-education.

At this moment, so critical in the career of the youthful engineer, the insufficiency of material resources is the cause that the majority take service, at a very low rate of remuneration, as draughtsmen in the drawing office of mechanical works, or in the drawing offices of railway companies; others more fortunate enter works in the quality of artizans; but even they are hardly to be envied, simply from the fact that in the majority of cases the specialty of the first works, which they happen to enter, becomes their own specialty through life. An experienced observer will find no difficulty in perceiving all the inconveniences to a technical education, which arise as the result of such an order of things. Let us explain this by examples. A young man, having received thorough scientific preparation in a polytechnical school, has entered as artizan practician some extensive joiner works, and in a year or two begins to serve in the capacity of a workman, receiv-

ing pay from the works. If, from any circumstance whatever, he becomes deprived of his place, he finds it necessary to seek another in a similar joiner works, or else to enter again as practician in another specialty, for instance, a locomotive, boiler or other works. The material resources of young men preclude, in the majority of cases, the possibility of their deciding on the latter alternative.

If the observant Directors of Polytechnical Schools should take upon themselves the work of following the industrial career of the contingent of their pupils, who on leaving school enter a drawing office, they would easily perceive that those young people experience extreme difficulty when they are once engaged there in leaving such an office, and in the majority of cases remain draughtsmen all their lives. In such offices a young man acquires but very inconsiderable technical information, neither can they in any way serve him as practical schools for his further self-instruction. And we must here observe, also, that the more extensive the works, and consequently the drawing office attached, the fewer are the advantages offered to the young practician, since he has to do with an institution in which division of labor, forming an essential principle, will not admit of his becoming speedily acquainted with the general progress of work. We cannot but add that this principle having become latterly extensively applied in all large works and mills, though on the one hand bringing considerable material advantages to the proprietors, has, on the other, greatly influenced the depreciation of the level of technical knowledge among the workmen, by confining that knowledge within the limits of narrow specialization.

The technical education afforded to young men in almost all the Polytechnical Schools of Europe leaves, theoretically speaking, little to desire, but is exceedingly imperfect practically, and demands the particular attention of those persons who are entrusted with such instruction.

The peculiar circumstances, by which the young people who have finished the course of the Polytechnicums find themselves surrounded, do not admit before their entering upon an active life, of the acquirement of even a superficial general practical education, but place them in the necessity of devoting all their activity from the first day of their leaving school, and often their whole life, to a narrow specialty. The attention of the Directors of Polytechnical Schools has often been drawn to this, and attempts have frequently been made to familiarize young people at school with the practical work of mechanics, but all these endeavors have proved to be unattended with success from the following reasons:

1. The school workshops for the practical occupation of the students were constructed on a very miniature and inconsiderable scale.
2. The consequent want of room in these workshops did not admit of all the students being occupied at the same time, and therefore their attendance was not obligatory, while the majority of the professors and masters expressed their disapprobation of such employment.

3. There existed no systematical method of practical instruction in the workshops similar to that which had been applied to the practical teaching in the chemical laboratories.
4. The material resources assigned for the maintenance of the school workshops were very inadequate.
5. The time allowed for the full course of study in the Polytechnical Schools was insufficient to admit of the combination, in that course, of theoretical with practical instruction in technology.

Though there have appeared some literary articles against the introduction of practical instruction with workshops into the higher technical schools, yet it is our subjective opinion that those articles appeared only in defence of the existing order of things, and to justify a certain lukewarmness in introducing advantageous measures, but no demonstration of the results of trial were afforded among the arguments against such a mode of instruction, for the simple reason that excepting feeble attempts, no serious experiments have been made. Even those attempts themselves were made without any particular energy and due observativeness.

We do not here take into calculation some of the at present existing technical schools of France, which possess sufficiently extensive school workshops,[1] because those schools belong rather to the lower class technical institutions, and do not give to the world mechanical engineers and constructers, but only foremen (contremaitres).

The slight acquaintance of learned technologists with practical work in mechanical workshops, entails the unfortunate consequence that in the greater number of even very extensive works the practical part remains in the hands of routined artizans who have received no scientific instruction, but who have attained their exceptional position by accustoming themselves during the course of many years to the most obsolete methods of practice in the mechanical art.

Seldom do the rays of science penetrate that unenlightened sphere of labor, and, meanwhile, it has so long demanded scientific guidance.

The Imperial Technical School of Moscow, the course of which, from the theoretical subjects taught therein, equals the course of many of the Polytechnical Schools of Western Europe, combines theoretical with practical education, and consequently is enabled to present real proofs of the possibility and advantageousness of such combination, since the trial of this combination has been made on an extensive scale, and during a considerable length of time.

Every thing that we have exhibited at the international exhibition relates exclusively to this, in our opinion, important question, and was exhibited in the desire of sharing with specialists in the

[1] These are the schools of Chalons, Aix and Angers.

work of technical education in the New World, all those results which have been attained by the School in the independent investigation of this special question.

For the practical education of young men in the two branches,— mechanical engineers and mechanical constructers[1]— the school possesses large mechanical works with hired workmen, accepting and carrying out orders from private individuals, and on a commercial footing, for the construction of steam engines, working engines, pumps, transmissions, agricultural machines, etc.[2]

The works consist of the following shops: Joiners' shop, Engineers' shop, Erectors' shop, Painters' shop, a large Forge with steam hammer and fan blast, iron foundry with furnace for 3000 kilogr. of metal, and brass foundry; the works have also a drawing-office and counting-house attached to them.

A steam engine of thirty horse-power is used for the working of the place, while the foundry with fan blast and coal pulverizing-mill are worked by an engine of ten horse-power.

The works are under the management of the head mechanical engineer (vacant) and his assistant, Platonoff, mechanical engineer.

The drawing-office is in the charge of Petroff, mechanical engineer. All the mentioned persons have passed through the course of our school.

These works being within the walls of the institution itself, and managed by well-instructed technologists, would be of important assistance in the instruction of young people, even if the young people took no active part in the practical working of them.

But in order that the pupils may derive the greatest possible advantage from such auxiliaries, the school possesses, apart from the mechanical works, and intended solely for the use of the pupils, school workshops: joiners' shop with turning lathe, pattern shop, metal turning, fitters' shop, smithy and moulding shop.

Every one of these shops is under the management of a technologist — specialist,[3] or of a skilled workman, and their duty is to instruct the pupils in the rudiments of mechanical labor.

Every young man becomes acquainted, by fulfilling the obligatory programme, with all the work of mechanical art, namely: turning, fitting, carpentering and forging, in the school workshops, and only then is admitted to the mechanical works.

We shall endeavor to speak further, on the system of teaching the arts in the mechanical workshops of the school.

Up to the present time throughout the world, the workmen at industrial works and mills are usually self-taught. Any one who

[1] Young men studying the technological engineering branch are admitted to the laboratories instead of the mechanical workshops.

[2] These works execute private orders to the sum of from 35,000 to 46,000 dollars annually.

[3] The wood turners' shop is in charge of Mr. Adelmann, the smithy — Mr. Bouroff, carpenters'— Mr. Michaeloff, metal turners'— Mr. Markoff, moulders'— Mr. Koumenius, and the fitters' shop—Mr. Sovetkin, mechanical engineer.

has himself been employed at works, and is familiar with the daily life of the workman in the different countries, must have perceived that the acquirement of knowledge and skill in any trade is to him a process much similar to the following: a boy of thirteen or fourteen years of age having entered a mechanical works to learn his trade, is put during the first few years, to work of an entirely unproductive kind, and which has not the slightest relation to technics. He is made to carry water, sweep the workshop, crush emery, grind colors, etc. Only after the lapse of a few years, and probably, thanks to accidental circumstances, a chisel or a file is put into the hands of the youth, and he is set to perform the rudest and simplest kind of work.

Then, also, if he happen to have neither father nor brother among the workmen around him, he begins learning his trade without a guiding hand, and thus commences acquiring practical knowledge and skill in his trade by observing those about him in the workshop, and by his own thought and calculation, and impelled by the sole desire of attaining in as short a space of time as possible the position of a paid hand in the works. There can be no doubt that under such circumstance the acquirement of skill by the new generation of workmen takes place in an extremely irrational manner, and without any system; the amount, of knowledge obtained depends upon accident, and the time thus employed is of disproportionate length. Besides this, there is yet another inconvenience, namely, that of specializing labor to too fractional a degree. The young workman, placed accidentally either to a drilling or planing machine, or a self-acting lathe, endeavors to remain as long as possible at his machine, encountering, it will be understood, no objection on the part of the heads of the workshops, since such specialization of labor redounds to the advantage of the proprietors, owing to the abundance of hands.

This order of things has the deplorable result, that notwithstanding the long continued stay of the young workmen at mechanical works, and which is sometimes prolonged through the major part of the years of their manhood, well-taught and skilled fitters are almost everywhere rarely to be met with. This will be confirmed by all those constructers who demand skilled labor for the erection of models, and of the more or less delicately constructed instruments, machines and apparatus.

During the past few years endeavors have been continually made to open schools for the instruction of the workmen at all works of any considerable extent. The subjects taught in these schools are free hand and linear drawing, arithmetic, and many others, in the supposition that practical knowledge of works will be acquired in the works themselves.

From this it is impossible to conclude otherwise than that society, while taking measures to civilize the working classes, gives, at the same time, no attention whatever to the manner in which the

young workmen acquire practical experience in their trades at the works; no endeavors have been made in that respect, and, meanwhile, as is our subjective opinion, the question is worthy of particular attention.

The conclusion, however, forces itself upon us that this question can hardly be entered into until the young well-taught technologists, leaving Polytechnical Schools, shall themselves possess rational experience in practical hand labor. In order that their education as specialists shall be full and ample, such knowledge is indispensable in the highest degree, though until the present time, it has unfortunately presented a prominent deficiency in their instruction. Who will not admit that the knowledge of the manner of executing given work is a necessity to one who has to issue the project of such work?

Acting on the principle that mechanical engineers and mechanical constructers, whose future activity will be devoted preeminently to mechanical works, should have practical experience in the mechanical arts, the imperial Technical School has employed every necessary measure for the solution of this difficulty in the best possible manner.

In 1868 the School council considered it indispensable, in order to secure the systematical teaching of elementary practical work, as well as for the more convenient supervision of the pupils while practically employed, to separate entirely the school workshops from the mechanical works in which the orders from private individuals are executed, admitting pupils to the latter only when they have perfectly acquired the principles of practical labor.

By the separation alone of the school workshops from the mechanical works, the principal aim was, however, far from being attained; it was found necessary to work out such a method of teaching the elementary principles of mechanical art as, firstly, should demand the least possible length of time for their acquirement; secondly, should increase the facility of the supervision of the gradationary employment of the pupils; thirdly, should impart to the study itself of practical work the character of a sound, systematical acquirement of knowledge, and fourthly, and lastly, as should facilitate the demonstration of the progress of every pupil at every stated time. Everybody is well aware that the successful study of any art whatsoever, free hand or linear drawing, music, singing, painting, etc., is only attainable when the first attempts at any of them are strictly subject to the laws of gradation and successiveness, when every student adheres to a definite method or school, surmounting, little by little, and by certain degrees, the difficulties to be encountered.

All those arts, which we have just named, possess a method of study which has been well worked out and defined, because, since they have long constituted a part of the education of the well-instructed classes of people, they could not but become subject to

scientific analysis, could not but become the objects of investigation, with a view of defining those conditions which might render the study of them as easy and regulated as possible.

This, however, cannot relate to those arts which have been hitherto pre-eminently followed by the common and imperfectly educated class of workpeople, but a knowledge of which appears at the present moment, to be of importance to the educated technologist.

These arts are: wood-turning, carpentering, metal-turning, fitting and forging. From what we have already said, it will not be difficult to arrive at the reason of the absence of a strictly systematical method for the study of them, nor why the active working out of such a method, without the aid of enlightened minds, may long remain deferred.

Meanwhile the necessity of such a method, more particularly for technical educational establishments, admits not of the slightest doubt, and the filling-up of this want promises evident advantages, not only in the matter of scientific technical education, but also with regard to the practical instruction of the work people, and consequently, the perfection of mechanical hand labor itself, which, from the introduction of specially adapted machinery is, year by year, perceptibly deteriorating.

If we except the attempts made in France in the year 1867 by the celebrated and learned mechanical engineer, A. Cler, to form a collection of models for the practical study of the principal methods of forging and welding iron and steel, as well as the chief parts of joiners' work, and this, with a purely demonstrative aim—no one, as far as we are aware, has hitherto been actively engaged in the working out of this question in its application to the study of hand labor in workshops. To the Imperial Technical School belongs the initiative in the introduction of a systematical method of teaching the arts of turning, carpentering, fitting and forging.

To the knowledge and experience in these specialties of the gentlemen entrusted with the management of the school workshops, and to their warm sympathy in the matter of practical education, we are indebted for the drawing-up of the programme of systematical instruction in the mechanical arts, its introduction in the year 1868 into the workshops, and also for the preparation of the necessary auxiliaries to study. In the year 1870, at the exhibition of manufactures at St. Petersbourg, the school exhibited its methods of teaching mechanical arts, and from that time they have been introduced into all the technical schools of Russia.

The auxiliaries of education employed in teaching mechanical arts were exhibited at the international exhibition of Vienna, and now at Philadelphia, in order that specialists in these matters might become acquainted with them.

The auxiliaries of education appointed for the teaching of any mechanical work whatever, for example—fitters' work, are classed

in three categories; to the first of these belong the collections of instruments employed in fitters' work, with which the beginner must make himself perfectly familiar before entering upon work, and afterwards to use these instruments during the execution of the work itself.

To this category relate all those collections of models indispensable to the teacher of fitters' work, for the purpose of demonstration: the collection of instruments most in use for measuring, full size; the collection of instruments, full size, for drilling metals; the collection of instruments, full size, for finishing, from the smithy to the fitting shop inclusive.[1]

Models of files, increased to 24 times the ordinary size, for the purpose of demonstrating the surface of the incision; the collection of models of instruments employed in cutting screws and nuts, increased six times ordinary size, for the study of the direction of the angles of incision; the collection of models of drills, increased six times, for the practical study of the cutting angles; and lastly, the collection of instruments and apparatus for teaching the tracing of yet unworked metal articles. We consider it our duty to draw the attention of specialists to this last collection, for the organization of which we are indebted to our skilful instructor of fitters' work, Mr. Sovetkin, mechanical engineer.

To the second category belong the collections of models appointed for the systematical and gradationary study of hand labor in the fitters' art. These collections have the same signification with regard to the work of fitting as is allowed to scales and exercises in instruction in music. They are so ordered that the beginner may be enabled to overcome by certain gradations the difficulties which present themselves before him. It will be sufficient to glance at the adjoined detailed list of objects contained in these collections, and to examine attentively every object exhibited, to be convinced, that if the pupil, under the guidance of the teacher, carefully fulfils the study of all the numbers embraced in the collections, or rather the educational programme of the art of fitting, he must inevitably, and in the most rational manner, render himself familiar with all the known practical hand labor of this art.

Hence we arrive at the conviction, without any difficulty, that with such a system of teaching art, the supervision of the teacher over the pupils, and his observation of their progress, become exceedingly easy. He need only remark that every number of the programme is executed satisfactorily by the pupil, and putting the following one before him, give the requisite explanations for the succeeding work.

In such a case, the fact of a great number of pupils being occu-

[1] This beautiful and ample collection could not be sent to the Exhibition in consequence of the limited space allotted to us.

pled at the same time will present no great disadvantage, nor will it increase the arduousness of his duty to any considerable degree. And further, it will be a matter of impossibility that a pupil who has been working during a few years in the workshop, should fail to be able to use the drill, or to trace a part to be worked, though he handle satisfactorily the chisel or the file.

To the third category belongs the collection of such articles, or parts of machines, as in the execution of which all the practical hand labor of the fitter's art is successively repeated, having been acquired during the studies of the previous course.

What we have said in relation to the manner of study of the work of fitting, must be accepted also with regard to the other branches of labor, namely, wood-turning, carpentering, smithy and foundry work. We exceedingly regretted that the limited space allotted to us in the exhibition did not admit of our exhibiting all those collections of auxiliaries to instruction which the School has produced.

In conclusion, we consider it our duty to observe that eight years have already elapsed since the programmes of instruction in the mechanical arts were introduced into the workshops of the School, and they have been found to attain in the most brilliant manner the aim proposed in their introduction.

VICTOR DELLA-VOSS,

Director of the School, and Ex-Professor of Practical Mechanics at the Agricultural and Forest-Academy Petrofsky-Rasoumofsky.

Next I include a condensed catalogue of the exhibit of this School, showing the collections of tools pertaining to each kind of work, and the number of samples which each student must make in each shop. Attention is particularly called to the admirable series, N, O, P, of enlarged models for the practical study of the construction of cutting instruments, in the "School Fitting Shop."

SCHOOL WORKSHOPS.

I. WOOD TURNERY.

MASTER F. ADELMANN.

A. Collection of tools (about 150) for turning wood.
B. Part I. Samples (13) for the successive learning of turning in wood.
Part II. Casting-mould models of details and Machines (30).

II. MODEL JOINERY.

MASTER A. M. MICHAELOFF.

C. Collection of tools (34) for joinery.
D. Collections of tools (46) for joinery. Second series.

E. Samples (25) for the successive learning of joinery and pattern making.
F. Collection of models (25) of usual wood-joinings.
G. Collection of patterns (18) for iron castings.

III. FORGING.

MASTER S. BOUROFF.

H. Collection (60) of forging tools.
I. Samples (79) for the successive learning of blacksmith's manipulations.

IV. METAL-TURNERY.

MASTER A. M. MARKOFF.

J. Collection of tools (55) for turning metal.
K. Collection of tools (75) for turning metal. Second series.
L. Samples (38) for the successive learning of turning metal.
M. Samples (21) for the successive learning of turning metal. Second series.

V. SCHOOL FITTING SHOP.

MODELS FOR THE PRACTICAL STUDY OF THE CONSTRUCTION OF CUTTING INSTRUMENTS.

MASTER D. K. SOVETKIN, MECHANICAL ENGINEER.

Taking into consideration the importance of a knowledge of the proper construction of instruments, and the difficulty which has to be overcome in explaining to a whole mass of pupils the minutest details in connection with the direction and the angles of the incisive portions of instruments, we, already in the year 1872 endeavored to construct wooden models, representing instruments on a considerably increased scale. Part of these models was exhibited by us at the Polytechnical Exhibition of Moscow, in the year 1872.

Models of instruments on an increased scale present the advantage of rendering it possible for the student to see clearly all the minutest details of the construction of the instrument. The direction of the cutting edges, and also the shape and direction of the level surfaces which form the working part of an instrument, should be studied in the most detailed manner, and how is this possible when these portions of an instrument are hardly to be seen by the unaided sight. Let us take for an example the cut of a smooth-file; is it possible to form a clear comprehension of the shape and direction of the teeth without the aid of the lens? Certainly not. If, then, we form the tooth of the file, increased to twenty-four times the ordinary size, all the surfaces around it will be presented as practically clearly, as will enable one not even engaged in the special study of the matter, to form a clear idea of the shape of the tooth of the file. At the present moment we

submit to the appreciation and judgment of the interested public models of the cutting parts of files, drills and instruments for the cutting of the screw, outside as well as inside.

The three following lists will serve as the basis of the entire range of the collections, which represent all the instruments employed in work.

N. Models of drills and countersinks increased six times the ordinary size.

1. Model of cutting edges of a drill (double cutting) for drill-bow.
2. Model of cutting edges of a drill (one cutting) for drill-bow.
3. Model of cutting edges of a drill for crank-brace.
4. Model of cutting edges of a center-bit with long point.
5. Model of cutting edges of a center-bit with short point.

Remark. In models No. 1–5, are clearly shown the shapes of the cutting edges, and also the angles of the working surfaces. From an examination of these drills it will be easily seen the work of such instruments cannot be called good by reason of the irregular direction of the working surfaces.

6. Model of cutting edges of a drill, which edges have the favorable angles for the work.
7. Model of cutting edges of an American spiral-drill, distinguished by stability and exact work.
8. Model of cutting edges of a drill for boring turning-joints.
9. Model of cutting edges of a drill for half-ball borings.
10. Model of cutting edges of a fashion drill.
11. Model of cutting edges of a cone-countersink for wrought-iron and cast-iron.
12. Model of cutting edges of a cone-countersink for brass.
13. Model of cutting edges of a hemisphere countersink.
14. Model of a drill-stock with the cutter, showing its cutting edges and fastening.

O. Cutting parts of files increased twenty-four times ordinary size.

1. Tin-file.
2. Rasp-cut for lead and soft allayage of metals.
3. Sample of the first-course of files for hard metals, in order to show the angles of the working surfaces and cutting edges.
4. Sample of the first course and the second course, in order to show the beginning of file-teeth.
5. Sample of the first course of a smooth-file, in order to show the angles and form of the working surfaces.
6. Sample of the second course for smooth-files.
7. Sample of the second course of a fine cut rasp, in order to show the proportions of teeth.
8. Sample of the second course of an armfile, in order to show the proportions of teeth.

Remark. The three last samples show clearly and practically the size of the teeth of the most used files.

P. Screw-cutting tools, increased six times ordinary size.

1. Model of a screw-tap with conical nucleus and thread.
2. Model of a screw-tap with cylindrical nucleus and conical thread.
3–6. Models of screw-taps for nuts having holes not going through (complete assortment).
7. Model of part of a screw-plate for cutting external screw-threads.
8. Models of screw-dies with obtuse cutting angles.
9. Models of screw-dies with right cutting angles.
10. Models of Whitworth's screw-dies.

Q. Collection of instruments (about 90) employed in making apertures of various shapes.

R. Collection of instruments of measurement (43) used in studying the art of fitting.

S. Course I. Time for study, 240 hours. Samples (28) for the successive learning of the filer's trade.

T. Course II. Time for study, 240 hours. Samples (23) for the successive learning of the filer's trade.

U. Course III. Time for study, 240 hours. Samples (24) for the successive learning of the filer's trade.

Remark. The method of systematically teaching the art of fitting was first worked out in the Imperial Technical School of Moscow in the year 1868, and after eight years' trial has proved of immense advantage to the School itself, as well as to those of the Russian technical schools which borrowed that method of the Moscow Technical School at the time of the Petersburg exhibition of the year 1870.

In attestation of the utility of the proposed systematical method of teaching, we may observe that immediately after its being presented to the public in the year 1870, the Imperial Technical School received orders for similar collections from technical schools in Moscow, Petersburg and Odessa.

V. A bench, instruments and apparatus (13) for marking and lining machine-parts to be worked.

W. Collection of models (11) for the demonstrative instruction in the marking and lining; the red lines represent the geometrical axis, and the lines according to which the work must be carried out.

In all that precedes, I have endeavored to set forth, as clearly as I could, the general considerations upon which this system of shop instruction is based; to show that the solution of the problem has been approached from the instruction side, and not from the construction side, and in this consists its fundamental and thoroughly practical character, as part of a system of education. The system presupposes the student's ignorance, and begins at the foundation, both in theory and practice. Every step well taken from such a beginning is a clear gain, and the successive steps have only to be taken to arrive at the goal of success. The com-

plete demonstration, however, is seen in the results exhibited at Philadelphia — results which no mixed, or less systematic system could possibly produce.

Another value of the system is, that it is equally well adapted to the wants of each class, or grade, of students. If one wishes to be a mechanical engineer, and finds that he has the ability to master the highest theoretical questions involved, the amount of shop work will be graded to meet his needs; if, on the other hand, the student looks forward to the rank of a first class machinist, he will need more mechanical dexterity, and will therefore work out a larger number of examples, and be required to do less in the higher mathematical and theoretical studies.

It is also an exceedingly important feature of this system that the instruction shops are the least expensive to equip and maintain — and further, it is not necessary for the highest success of this instruction that construction shops should also be immediately connected with the school, either as at St. Petersburg or at Moscow. The young engineer, or machinist, after graduating in such a course, will find no difficulty in completing his practical education in great manufacturing works, and probably under circumstances quite agreeable to those who have already spent all they could borrow to complete their chosen course of study. Further, the system applies equally to all industrial arts needing manual skill.

Even, now, the Department of Industrial Design, established in this Institute four years ago by the Trustee of the Lowell Institute, and which has in this short time attained such marked success, needs that its course of study should be materially widened and enlarged before it can take rank as a school of technical education in the textile manufactures. Practical instruction in weaving, the study of the fibrous materials used in the various fabrics, with the operations of spinning, scouring, fulling and finishing, should be added. Systematic school instruction in such specialties has so long existed abroad as to have become a recognized element in the quality of their textile manufactures. If Massachusetts expects to keep the lead in the quality of her industrial work, it must be done by the establishment of technical schools for teaching the manipulations, with such other special knowledge as each

particular art requires. In each case the details must be worked out simply as an educational problem, and the instruction put in charge of an expert specialist, who understands theoretically and practically the particular manipulation. With the same skill, energy and perseverance, as are needed to command success in the teaching of any subject, we shall not fail of corresponding success in the teaching of practical industrial art. With the ability to make will come the desire to create, to those who have the capacity to rise into the higher realms of their chosen art.

In the light of the experience which Russia brings us, not only in the form of a proposed system, but proved by several years of experience in more than a single school, it seems to me that the duty of the Institute is plain. We should without delay, complete our course in Mechanical Engineering by adding a series of instruction shops, which I earnestly recommend. The whole matter turns upon getting the proper rooms. It is already clear that there are no other difficulties which can not readily be surmounted. With such shops once established, we shall also be prepared to offer instruction to those who wish to become constructers, rather than engineers, and especially to the large class of pupils to whom such a systematic training, properly supplemented with other studies, would prove a valuable foundation for further study, or for business. For these classes of students I propose the following outline of a

TWO YEARS' COURSE IN PRACTICAL MECHANISM.

To be admitted to this course the applicant must be at least fifteen years of age, and must pass a satisfactory examination in the following subjects: — Arithmetic, Geography, Spelling, Punctuation, English Composition, English and American History, and Algebra through simple equations.

FIRST YEAR.

		No. of Exercises	Hrs. per week
Shop Instruction		120	12
Algebra	1st half	45	3
Plane Geometry.	2d half	45	3
Rhetoric and Composition		90	3
Mechanical and Free Hand Drawing . .		90	3

SECOND YEAR.

		No. of Exercises	Hrs. per week
Shop Instruction		120	12
Algebra finished	1st half	45	3
Solid Geometry	2d half	45	3
English Literature		60	2
French		90	3
Mechanical and Free Hand Drawing . .		90	6

With the sets of samples of shop-work which will come to us at the close of the exhibition at Philadelphia, and the averages of the times needed to make each, taken from the shop records, and other information kindly promised by Dr. Peters, we shall be able to start with reliable data upon which to build.

JOHN D. RUNKLE, *President.*

Mass. Institute of Technology,
Boston, July 19, 1876.

SUPPLEMENTARY STATEMENT.

Since the issue of my report upon the Russian system of shop-work instruction for engineers and machinists, so many persons who have read it have asked me if I would give them a simple, concrete illustration of the system, that I fear I may have failed to make the matter entirely clear, and I will try, in a simple way, to present the idea, which would be entirely unnecessary if I could only show the series of instruction-samples made in the several shops, now on exhibition at the Centennial.

Clearly, the first step in practical mechanism is to teach the use of tools. Suppose that we have, say, fifty young men to teach. Now we can put the same tool or set of tool into the hands of each, and teach all together, as a class, or we can put a different tool or set into the hands of each, in which case the instruction becomes special to each, or individual instruction. In the first case, one teacher can systematically teach the whole class, and in the second case, to give each pupil equally good instruction, it will need as many teachers as pupils, without some of the teachers happen to be experts in the use of more than one set of tools; and at best it would clearly require in the second case several teachers. It must be plain that on all accounts it will be best to follow the class system, and teach all the use of the same tool or set of tools at the same time. It follows, then, that our shop must be fitted with fifty sets of tools, if this happens to be the number of students which can be well taught at once.

Now, it is plain that, to learn the use of the set of tools selected as the beginning of the course, a certain number of forms must be worked out, the number being determined by the amount of skill which it is important the particular class under instruction should acquire. Next, what should guide us in the selection of the forms to be worked out? If we examine a certain number of constructions, say machines made entirely of metal, we shall find that some of the parts are made or finished with the set of tools under consideration. Now, it is not necessary that we should select these

exact forms, but the whole end will be gained by devising and working out a series of typical forms, each of which will only vary from the actual ones to a limited extent, according to the special construction in which it may be needed. When the course in the first shop, say the filers' shop, is finished, the class is put into a new shop to learn the use of another set of tools, and so on until the use of all the tools used in the construction of wood and the metals is learned. It will be seen, then, that the samples made in each shop are made simply and only for instruction, in order that no conditions may enter to interfere with the system best adapted for this end. Next, it must be remembered that while the class is learning the manipulations of each set of tools, and thus learning at the same time to construct a *typical alphabet of mechanism*, the theory involved in the construction of the tools is systematically taught, — that is, the reason why each tool is so made and how it must be kept in order. Besides, each sample is made from drawings which the student has previously made, thus making this instruction also conform to actual practice.

Thus far the whole aim has been to give the student skill in the use of all the tools pertaining to the course, and now, and not before, he is prepared to be transferred to a construction shop. The Russian system is then a fundamental analysis of the problem of practical mechanism, and consists in teaching the theory and use of tools to classes of students in the same orderly and progressive way in which any other subject is taught, with the same supervision and instruction of a specially qualified teacher, holding each student to the same account and giving him the same credit as in other studies. In this way of teaching it the study of practical mechanism also becomes a discipline of positive value in a system of instruction. The theories involved in the construction of machinery have nothing to do with learning the use of tools, and the entire aim in a construction shop is the production of results based on the skill of the workmen engaged.

In addition to the foregoing analysis it will hardly be necessary to extend this letter, by showing in what ways a shop arranged for construction is unfitted for the class system of instruction in the use of tools, even if such a shop could be devoted to this purpose. I hope I have now made the Russian system plain to all who will take the pains to give the subject a little thought, and particularly from the educational point of view. As a system, it is fundamental, applicable to all industries needing manual skill, easily manageable as an element in a systematic course of instruction, economical of the time of the student, and of the funds of the institution. When the manual skill of the student has a commercial value, as it will have when he has thoroughly mastered the course upon the use of tools, then he will be of value in a construction shop; and it only remains to ask whether this shall be a school-shop or one of the great manufacturing establishments with which our country abounds. I presume that but little time need be spent upon the answer.

The students' skill is worth more to a manufacturing establishment than it could be to a school, even if manufacturing was one of the proper functions. Besides, under the best supposable circumstances, all the economic conditions upon which success in manufacturing depends could never be realized in a school-shop. Therefore our aim will be to build up the instruction-shops authorized by the Corporation of this Institute, and leave the young engineer or machinist to enter at once upon the broad field of his chosen career, for which he should be well fitted if he and his instructors have faithfully done their duty. It is not necessary for a school to

operate a railroad to teach its civil engineers, nor work a mine to teach its mining engineers, nor maintain a menagerie to teach natural history.

JOHN D. RUNKLE.

Massachusetts Institute of Technology,
Boston, August 21, 1876.

NOTE.—INDUSTRIAL ARTS IN THE PUBLIC SCHOOLS.

Extracts from "A Report of the Committee on Education, made to the House of Representatives of Rhode Island, at its January session, 1877, by Henry H. Fay, Chairman."

The subject is considered under the following heads:—

1st. The proper limit of free education.

2d. The importance of the High School in the system.

3d. The variety and kind of instructions in the schools.

4th. Industrial Art Education.

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Industrial Art Education.

Recognizing the fact that our public school system is not perfected beyond criticism or improvement, and that it is progressive in its nature, as well as elastic in its adaptation to the wants of the people, we must take cognizance of the sentiment quite prevalent in the community, that the results are not fully commensurate with the expenditure of money, and that the element of "practicality" is not as large a factor as it should be, in the great educational problem of the period. The importance of this opinion is acknowledged by the warmest friends of public education, and the popular demand has become so urgent, that at last it has found expression in that part of the resolution before us, requiring a consideration of the question of industrial art education in the public schools.

The subject of industrial education is by no means new, and were it only the *general* subject, referred to us, the task would be easier than now, since we are confined to the specific consideration of its aspect as an integral part of our present established system, or at least a supplement of it. We find that we are not the only inquirers upon this subject, as our investigations have developed the fact that, in all parts of our country, the subject has recently risen to prominence, and school-boards, educators, and legislators, are seeking for information. The National Board of Trade of the United States has interested itself in this matter, and in January last, sent a memorial to this General Assembly, as to each of the legislatures of the other States, reading as follows:—

"Your memorialists, representing merchants and manufacturers of the United States, beg leave respectfully to represent unto your Honorable body, that the interference and dictation of Trades Unions, and similar organizations, with the system of apprenticeship in earlier times prevailing in this and other countries, the active competition of foreign manufacturers with American industries in both home and foreign markets, and the increased attention being given by governments abroad, to the development and improvement of skilled labor, by instruction in science and art, as ap-

plied to mechanics and manufacturing, renders it in the opinion of this Board of great importance to our material progress, that suitable provision be made for the establishment of Art and Science schools in each of the several States, where workmen and their children may receive such technical instruction as will improve and create skilled labor, to the end that the poorer classes of society may become better fitted for a higher development of industry, and our mechanical and manufacturing interests be enabled more successfully to compete with those of other countries; therefore, your petitioners would respectfully pray that your Honorable body will adopt measures for the establishment of such a school, or schools, as is herein indicated, within the State of Rhode Island.

Respectfully submitted, by order of National Board of Trade,

FREDERICK FRALEY,
President."

JANUARY, 1877.

NEGLECT OF INDUSTRIAL EDUCATION, A NATION'S WEAKNESS.

The Universal Exhibition in 1851 at London, bringing together, for the first time, so extensive a collection of the industrial products of all nations, enabled each one to obtain a correct view of its own condition compared with that of others. The succeeding exhibitions in 1856, 1861, and 1867, furnished valuable lessons to all of the European countries, but especially to England, whose utter discomfiture at the Paris Exhibition in 1867, led to systematic inquiries as to the reasons for the more rapid progress made in other nations in many of those industries in which, everything else being equal, the English ought to excel. Government commissioners, composed of representatives of the educated professions, applied sciences, engineering, education and manufactures, were sent to the Paris Exhibition, and a deputation of over fifty skilled artisans, also, whose reports all concurred in the statement that the superiority of other nations in industrial products was due entirely to the greater interest given to the industrial education of their people.

These statements, admitting inferiority on their own part, noting the rapid advancement of other countries since previous exhibitions, and attributing it solely to the one cause, were most startling, and thoroughly alarmed all Englishmen who had patriotic pride in maintaining for their country precedence in manufacturing and mechanical industries.

They examined continental systems of industrial education, published elaborate reports, and at once adopted such educational measures as were deemed useful to them. During the last ten years since the Paris Exhibition, England has made wondrous efforts in this direction, and her advancement in the industrial arts was made manifest by the many exhibits of her productions at the Centennial Exhibition last year. Meanwhile, other European countries, taught by experience, had also improved upon the industrial schools, which had given them the advantage of at least one generation of workmen, and were determined to continue in the lead.

The French manufacturers did not fail to note the extraordinary exertions England was making to contend for precedence in industrial arts. They called the attention of the Government to the matter, and demanded increased educational advantages, in addition to those already in existence. A government commission, upon full investigation, learned that their system was very defective in comparison with that of Germany, and the result was

an energetic movement on the part of the State and of parties interested, which has, long ago, worked a great improvement in every branch of industry.

Switzerland, Germany, Austria, Russia, and other countries, were alike stimulated by the necessity of the case, to renewed interest in all that pertains to the advancement of the arts of industry, and their schools, which had been good, were made better, while those which had been best of all were advanced to a still higher standard. The process of improvement is still going on, and will continue to receive the utmost attention in each country that hopes to compete in the markets of the world with the products of her industry.

However satisfactory may be the present development of Rhode Island mechanical and manufacturing industries; whatever there may have been of inventive genius, artistic skill or business enterprise, to arouse feelings of pride in our achievements in the past, we must not lapse into a spirit of self-complacency, but rather take to ourselves the lesson from the experience of other countries, that no State can secure and maintain pre-eminence in mechanics and manufactures except by the systematic and thorough training of the young in the industrial arts; that the palm of superiority, by an unfailing law, will surely go to that country where the *hand of the laborer is guided by a cultivated taste and a scientifically trained intellect.*

From the last census of this State, we learn that in every 1,000 of our population, 560 are engaged in manufacturing or mechanical industries, and this fact in itself is sufficient to give us an interest in the great question of industrial education, and should lead us to the adoption of any measures that furnish a prospect of success in solving this great problem.

It will be interesting to briefly note what has been done in European countries, where, as we have stated, the interest in this subject has become synonymous with their self-interest, and where the competition of different countries has compelled attention to it, under penalty of banishment from the best markets of the world.

Industrial Education in Germany.

The system of general education in Germany is well known as being most comprehensive, and as having been successful in reducing illiteracy toward its minimum, but in its arrangements for industrial education it is equally broad and systematic. The proportion of the population engaged in mechanics and manufactures is less than in Rhode Island, but there is no place of any considerable size wanting in some sort of instruction having in view the various industries.

"Improvement" schools, "Real" schools, "Trade" schools, "Weaver's" schools, and special schools of many kinds, are found thickly scattered over the entire country, affording facilities not only for general, but for special, technical instruction that are unsurpassed. In the lower order of these institutions, there is a similarity to our elementary schools, with the distinction that, *invariably*, the strictest attention is given to instruction in *drawing*. Of the secondary schools, we give the curriculum of one of the best, styled the "City-trade School of Berlin." It was founded "to give a more appropriate education for the mechanic arts and higher trades than can be had through the courses of the other schools," and has the city of Berlin as its patron. The subjects of instruction are Religion, German, French, English, Arithmetic, Algebra, Geometry, Geography, History, Natural History, Physics, Chemistry, Technology, Writing, Drawing and Vocal Music.

The school is provided amply with laboratories, apparatus, and all the paraphernalia of instruction, and technology is taught by describing and illustrating the different arts and trades by models and visits to workshops of which there are none connected with the institution. Pupils enter after they are twelve years of age, and remain five years to complete the course. Higher than this in order, and forming the summit in the grade of industrial schools, is the Royal Trade Academy at Berlin, which embraces in its course far more advanced mathematical studies, and has extensive workshops connected with it, where various branches of practical mechanics are taught. The pupil begins with the making of a screw, and proceeds in regular order to the most difficult mechanical operations.

An Industrial Drawing School in Berlin, also, trains designers of patterns for printing silk, woolen and cotton tissues, and paper hangings, together with all the theoretical and practical branches of weaving.

Among the large number whose organization we have noted, the Royal School of Machinery at Augsburg, in Bavaria, is interesting, devoting, as it does, more time to the practical side of mechanics. The requisites for admission are a thorough knowledge of Algebra and Geometry, and a certain amount of practice in linear drawing. The pupils, who must be fifteen years old, pursue a theoretical course in higher Mathematics, Mechanics, Physics, Drawing, etc., but devote an average of three hours daily to the workshops.

The scholar is placed at a vise, and a coarse file and a piece of iron are given him. He practices first in filing planes at right angles, and then parellel to one another, then he does the same with a finer file. Nothing can be done superficially, and no one can go on to other work until he has been thoroughly successful. Next, he is practised in boring, cutting screws and in making faucets. Then comes the turning of round surfaces and of screws, smoothing off, etc., all of which is done with simple pieces of iron, out of which paper-weights, etc., are made. Other simple operations follow until the end of the course, when scholars are generally able to support themselves by work in any factory.

Enough examples have been furnished to show the general scope and variety of industrial schools in Germany, and while from the hundreds of them in operation, covering very many special trades and occupations, we might select some of unusual interest, we have not space for the details in this report.

In Austria, the agencies for the education of skilled labor are of various kinds, and increasing in number. They have, as in Germany, the "improvement" and the ordinary technical schools, but the great impulse which the art-industrial movement has received during the last twenty-five years, has called into existence new establishments of a similar nature, but largely devoted to special trades and industries.

These comprise theoretical schools and school shops, in which the practical and theoretical teachings are combined. The number of these schools has increased in the last five years from *ten* to *one hundred and thirty*. In the highest of the industrial schools, nearly one-third of the time is devoted to free-hand and geometrical drawing.

France.

France is equally aroused with her continental neighbors to exertions for increased facilities for industrial-art education, and has rapidly augmented the number of schools for the elementary training of the young in this

respect. While perhaps, failing to equal Germany in the universality of the system, she compares quite favorably in certain localities, and in the higher class of technical schools.

In 1805, when Napoleon was First Consul, he visited one of the government institutions and was extremely dissatisfied with the answers of the pupils about to graduate, as to their intentions for the future. These, he said, unless they entered the army, would become a "burden rather than an aid to their families." He had observed workmen in the manufacturing establishments who were experts in the manual labor of their trades, but deficient in the theoretical part, and hence he determined to change the course at this institution, so that it should be devoted to "the study of trades, with so much theory as is necessary to their progress." This was done by an order soon after published, and the result has been one of the most successful institutions in the world for this purpose, at Chalons.

The plan has been modified during the last few years, so that instead of teaching a number of trades, it is devoted to general mechanical industries for which theoretical knowledge is indispensable. The shops connected with it are the Pattern shop, Smithy, Foundry and Fitting shop The pupils, who must be fifteen years of age, devote five hours or more daily, to the workshops, in which the general plan of instruction and practice is very similar to that previously described at Augsburg.

The general principles are, to make only one piece of the same kind, and to do all work, as far as practicable, by hand, and with the simplest tools. The school curriculum embraces Mathematics, Drawing, and the elementary branches.

Paris has numerous industrial schools of every grade, and throughout the country are found local institutions, often under the patronage of industrial societies, or established by individuals from philanthropic motives.

Notwithstanding all that had been done previously, a government report after the exhibition of 1867, states that "additional efforts must be put forth to maintain French industry at the level which it has reached, and enable it to meet the rivalry of other countries in fields, once by universal confession, exclusively their own."

The result has been, as in other countries, a period of remarkable activity in this direction during the last ten years, the beneficial results of which were seen in the display of industrial products at our Centennial, and will be far more evident at the next exhibition in 1878, on their own soil.

It would be a pleasing labor, if our time and space allowed, to note in detail the progress of other countries of Europe, and to give comparative views of their advance in industrial art education.

England, Holland, Italy, Sweden, Russia, and the other countries, have been actively working, and in each of them we find much to interest and instruct, but enough has been written to demonstrate the fact that in all of them the problem of industrial education is considered of vital importance, and that in its solution they are many years in advance of our own country.

Our own Country.

We have had in this country a few technical schools of a high order, whose pupils were instructed in the theory but not in practice, unless we except the chemical laboratory work. A prominent educator, connected with one of the best of them, remarked not long since: "Our graduates go out into the world with their brains well stocked with theories, but *with their hands tied behind them.*"

In occasional instances, institutions have been established where theory and practice were conjoined, as in the Worcester school, and the "Illinois Industrial College," with good results. The latter institution was established by the State of Illinois, in carrying out the intention of the act of Congress in 1862, giving grants of the public lands and prescribing, in return, the promotion of the "liberal and practical education of the industrial classes in the several pursuits and professions in life," as conditions accompanying acceptance. The State of Illinois has added liberally to the original fund, and the university now has property valued at nearly a million dollars, including a system of mechanical workshops and other paraphernalia for a complete industrial training.

In the State of Massachusetts much attention has been given to the subject, and throughout the State drawing has been taught in the public schools, being correctly deemed the true foundation of industrial art.

In Philadelphia, an association of private gentlemen organized the Pennsylvania Museum of Art, early in 1876, and took advantage of opportunities offered at the Centennial Exhibition to secure a large collection of industrial masterpieces to form the foundation of the museum, which like its prototype, the South Kensington Museum, in England, which within twenty years has revolutionized many branches of industry and created new ones, is expected to become an important aid to industrial education and culture.

The teaching of specific trades has often been urged, but the objections are so numerous, and the experience of the past so decidedly in opposition to such a plan, that aside from the difficulties arising from the option as to the particular trades to be taught, the expense of any general system would condemn it.

What is desired, is some system that will teach *the arts which underlie many industrial occupations*; something that will educate the hands and eyes; something that will furnish such a course of manual training as will enable our children, when they complete their course in the public schools, to secure some kind of employment, and not feel that they are incompetent to live, except "*by their wits.*"

If we can secure this, without limiting or abridging the usefulness of the system of education we now have in operation with such great success, we shall succeed in achieving for our day and generation and posterity, a blessing comparable in value with that which the founders of free public schools handed down to us.

In a careful study of very many systems of industrial instruction in Europe, we have found that all agree in one respect, namely, that *Drawing is an indispensable basis.* From the primary grades to the highest institutions of technology, Drawing is invariably a prominent feature of the curriculum. In all of these schools the same general principles are followed in uniting manual and mental instruction, and in familiarizing scholars with the use of tools. The details of instruction in the scores of schools we have studied, have differed more or less, but in nearly all of them the plan of manual instruction involved the methods of the apprentice system. In the school at Chalons, and also in that at Augsburg, there is an advance upon the old methods, but in Russia, at the Imperial Technical School at Moscow, they have taken an entirely "new departure" in manual education, by conforming it strictly to the system and well established principles which have proved successful in developing skill in other arts and sciences. By this system, they *analyze the processes requiring manual skill, and teach each process by itself to a class.*

The first principles are taught, and exercises in practice accompany them, leading the pupil on from the simplest to the most difficult manipulations. Just as in teaching one to play upon the piano, the "scales" and simple exercises come first and receive entire attention, rather than set tunes, which are tried only after months of preliminary practice; or, as in Drawing, the pupil first practices upon straight lines and their various combinations, and then after long exercise, attempts anything requiring skill; or, as in penmanship, the first efforts are upon lines, curves and parts of letters, before writing words; so, in manual instruction at this institution, the systematic progress of the pupil is the paramount consideration.

The collection of implements and pieces of machinery contributed by the Russian government to illustrate the work done at that school, formed an interesting exhibit in Machinery Hall, at our Centennial Exhibition, and furnished to interested observers a definite idea of the plan, system and results obtainable from it.

Massachusetts Institute of Technology.

In response to the polite invitation of President Runkle, who had been informed of the inquiry of this Assembly in regard to industrial education, we spent a day with him, for the purpose of receiving a full explanation of the plan, and of having ocular demonstration of the results thus far achieved. The pupils, since the commencement of the lessons, had completed the course in "filing," and we saw, in the results of only *eighty hours* of practice and instruction, such exquisite workmanship as could not be surpassed by an apprentice of two years' experience in an ordinary shop. We found a class of thirty-two boys at work on a "chipping" exercise, with hammer and chisel, under the instruction and constant supervision of an expert mechanic, employed as teacher of practical mechanics, and it was easy to perceive that the class instruction in this branch of education was as systematic and simple as the teaching of a class in Arithmetic or Grammar in our best public schools. Our attention was directed to the fact that these shops are for *in*struction, and not for *con*struction. The object of the labor performed is not to produce salable articles, but to impart mechanical skill, and hence the student can here receive systematic instruction, proceeding from first principles to difficult manipulations, while in ordinary construction shops an apprentice is taught only those things which accord with the convenience and profit of his employer. The fact that the instruction is given to so many pupils at a time, in class, is a marked economical feature, carrying out, as in so many other respects, the analogy with our general system of mental training.

Our space forbids a full description of the many interesting details which came under our observation, as well as any account of the testimony already given by practical and expert mechanics, as well as by thoughtful and skilled educators, as to the wonderful results already secured in this experiment of an altogether novel method of industrial training, but we are fully satisfied that enough has been shown, in the few months of trial, to warrant us in the opinion, that in this well-tried system, at once so simple and so economical, we can find a way to the solution of the great question of the *adaptation of industrial education to our existing system of mental training in the public schools.*

DEPARTMENT OF MILITARY SCIENCE AND TACTICS.

President J. D. Runkle,
Mass. Institute of Technology:—

SIR: I have the honor to render the following report of the status of the military instruction at the Institute during the school year of 1875–6.

The changes, made at the end of the last school-year, were based upon experience of the past, and the desire on my part to fix its status before leaving the Institute so that it should be satisfactory to all connected with it and, at the same time, give useful results. The experience of the year has justified the changes made; so far as the drill alone is concerned, it seems now to be placed so as to be satisfactory both to Faculty and students, based upon the premiss that military instruction shall, *must* be given in good faith. The end of the school year has found the battalion in an increased state of efficiency of drill and discipline. The instruction to the second year class, by lectures and recitations, was incomplete for lack of time to do even the minimum amount of work necessary, productive of a result that can be at all satisfactory. I most earnestly request that the time allotted to the second year work be increased by six exercises, making only thirty in all during the year.

The officers of the battalion during the year were as follows:

Staff Officers ranking as First Lieutenants.

Adjutant: E. F. Williams.
Quartermaster: I. Kirk.
Signal and Ordnance Officer: W. O Bradford.

Line Officers.

Captains: J. Rich, D. Pierce.
First Lieutenants: L. O. Towne, E. S. Draper, E. C. Miller.[1]
Second Lieutenants: R. Austin Robertson, Jr., Herbert Jaques,[2] F. P. Bronson.[3]

[1] Promoted previous to Centennial trip, vice Draper not accompanying the battalion.
[2] Vice Miller promoted. [3] Vice Robertson not accompanying the battalion.

Each and all of these officers performed the duties of their respective stations in a remarkably efficient and satisfactory manner; conscientious and impartial in the execution of their duties, they displayed great tact and judgment in their rather delicate relation with fellow students when assuming, *at stated times only*, the duties and relation of officers to subordinates. More than ordinary capacity was here required, and their ability to successfully perform the duties of their office at the school is a guarantee of their ability to perform similar or even duties of a *higher grade* in actual service.

CENTENNIAL TRIP TO PHILADELPHIA.

Many students were desirous of visiting the Centennial Exhibition, as it would present a vast field for study. On account of the expense involved, a large proportion would necessarily be prevented from attending, if only able to go individually. This objection would be obviated in a great measure if a number would unite in the movement. Enquiries were made to ascertain the cost, and it was found that if three hundred went, the expense of transportation to and from Philadelphia, board and lodging for two weeks would probably not exceed $25.00 per capita. The Corporation and Faculty therefore determined that the trip should be made.

The Corporation of the University of Pennsylvania courteously tendered the University Campus for a camping site. Efforts to get the necessary tents and camp equipage from the United States having failed, an act was passed in the State Legislature authorizing the loan of camp equipage to such schools as are, by the law of the State, required to give military instruction. We were thus enabled to procure the necessary outfit for camping. Through the intervention of Mr. Enoch Lewis, Mr. Phelan of Philadelphia kindly tendered us the use of sufficient lumber to floor the tents and for other purposes. Mr. Lewis procured for us, also, some engine head-lights to illuminate the Campus. Efforts were made to procure reduced rates of admission to the Exhibition, but they were unavailing.

Hon. Geo. B. Loring offered to us the use of the Massachusetts State Building as a place of rendezvous. Mr. and Mrs. Thomas Webster of Philadelphia were untiring in their efforts to secure for the Institute every facility which might be required. Professor Stillé, Provost of the University, placed at our disposal certain facilities which the University building afforded. Prof. Haupt, Prof. Richards and other Professors of the University aided us in many ways to perfect our arrangements.

Professor Robert E. Rogers, with the concurrence of the Medical faculty of the University, gave the use of a large room in the basement for a dining room, as also a number of other rooms for the use of such of the members of our Faculty as were accompanied by their wives. Prof. Ward and Messrs. Ross and Chamberlain did much, previous to and during our stay, to insure us every facility afforded in the building. Medical attendance and many courtesies were extended to us by Dr. Hammell, Superintendent of the Hospital of the University of Pennsylvania. A camping party, consisting of students, left for Philadelphia on June 1st. These laid out the camp, making the tent floors and pitching a large proportion of the tents. The labor performed by this party was severe. Arrangements were made for purchasing provisions and other necessary supplies, as also for the preparation and service of food.

On June 8th, at 4 P. M., the party, numbering something more than three hundred and seventy, started from the N. Y. & N. E. R. R. depot, in a special train for Norwich. The party consisted of members of the Corporation, Faculty, Graduates, former students, students and friends of members of the Institute. We were favored with being accompanied by a few ladies. At Norwich the boat was taken for Jersey City where the party arrived next morning at about 6 A. M. After some vexatious delay at this point, a special train conveyed the party to Philadelphia, arriving at about 10 A. M. The following regulations indicate the routine which was essentially followed during the encampment.

REGULATIONS.

1. The first three days will be devoted to a general inspection of the Exposition.

2. Thereafter the special subject of each day's investigation will be assigned by the head of the department in which the student is enrolled; and each student will be expected to conform to such directions as he may receive from the head of his department in the matter of his special work.

CAMP AND SANITARY REGULATIONS.

3. I. The daily routine will be as follows, viz.:

First Call for Reveille, at 6 A. M.

Reveille Roll-Call at 6.15 A. M.

At this hour every person, unless specially exempted, will be required to fall into ranks and answer his name unless sick. Bedding and blankets will be aired when weather permits.

Sick Call at 6.40 A. M.

Breakfast at 6.45 A. M.

Police Call at 7.30 A. M.

All persons will be required to aid in policing the grounds of the camp, and to put their respective tents in order.

Battalion Drill at 8.15 A. M.

(For the Institute Battalion only.)

Guard Mounting at 9 A. M.

The detail for the daily guard will be inspected and assigned to reliefs. The guard posted during the day will be detailed from the Battalion, and will be in four reliefs; each relief will stand guard three hours and fifteen minutes (in two tours), during twenty-four hours. Members of the guard will not be required to remain in camp, except while posted as sentries, and for one half-hour previous to their respective tours. *They must not, however, allow any chance to prevent their being in camp at the designated time for duty.* The guards posted at night will be detailed from students not in the battalion. Only one relief of the night guard will be permitted to go beyond the limits of the University grounds. The grounds will be thoroughly lighted, and a less number of sentries will be required at night; each relief will probably be posted only once during the night for not exceeding two hours.

Lunch at 12.30 P. M.

Dinner at 6 P. M.

Tattoo Roll-Call at 9.45 P. M.

All *Students* will be required to fall into ranks and answer their names, unless specially excused by the President. Applications for such absence must be made previous to 6 P. M. Blank forms may be procured of the Chief of Squad.

Taps at 10.15 P. M.

At this call all lights must be put out and perfect quiet observed in the camp. Whilst Graduates will not be required to answer their names at tattoo roll-call, nor to apply for permission to absent themselves from camp, they will be required to enter camp and retire noiselessly.

The before-mentioned hours may be changed if occasion requires. If it is found that the Exposition is open at night, the hour for tattoo roll-call will be so fixed as to permit students to remain until it is closed, and have ample time to return to camp. The hour for Reveille will, in that case, be also changed so as to allow at least eight hours for sleep.

4. All students will be required to perform a due proportion of guard, or such other camp duty as may be found necessary. These duties will be so arranged as to cause the least possible inconvenience and labor.

It is expected that the burden of each individual will be comparatively slight.

5. Failures to comply with the above regulations or any modifications of the same, or conduct reflecting upon the good name of the student, or of the Institute, will be met with dismissal from the camp, in which case the funds deposited will be forfeited.

To secure the uniformity of action necessary to avoid confusion, for purposes of police and cases of emergency, a Chief of Squad will be appointed for the members occupying each section of tents. An Assistant Chief of Squad will also be appointed to aid the C. of S in the performance of his duties, and to act for him in case of his absence. The Captains commanding Companies will act as C.'s of S. for sections A. and B.

DUTIES OF THE CHIEF OF SQUAD.

To call the roll at designated times and report unauthorized absence therefrom.

To superintend the police of the grounds in the immediate vicinity of the tents of his section.

To see to the proper arrangement of the tents, ventilation, airing of the bedding, proper disposals of debris, and necessary provisions against fire.

To report any needs for the comfort and well-being of his squad.

To ascertain if any members of his squad are unwell, and to cause them to report to the surgeon at sick call; in case of the patient's inability to move, the C. of S. will report the circumstances to the surgeon in order that the proper attention may be given.

To distribute at stated times the permits given each day for absence.

To aid at all times in the execution of such regulations as may be from time to time considered necessary.

The routine for Sunday will be as follows:

Reveille, Breakfast and Police calls, one hour later than during week days.

Battalion drill will be omitted.

Guard mounting at 9 A. M.

Dinner at 1.30 P. M.

Supper at 7 P. M.

Other calls same as week days.

One or two tents in each section will be assigned for bathing purposes, and tubs will be placed therein. If it is found that any waters in the vicinity can be used for swimming purposes, arrangements will be made to have a boat or other appliances for use, in case of emergencies. All are cautioned not to bathe immediately before or after eating, especially the latter.

A wagon was sent daily to the Exhibition Grounds with a luncheon which was served at the Mass. State building between the hours of 12 M. and 2 P. M. Every aid was given us by Gen'l Oliver, in charge of the building, and he was ever on the alert to add to our comfort and pleasure. Mrs. Vinton freely permitted us to use her kitchen with all its appurtenances. This arrangement enabled our students to enter the Exhibition Grounds in the morning and remain until evening without being put to any extra expense for a mid-day meal.

Hon. John Cummings, of the Corporation, who was in Philadelphia, aided us materially in getting permission from the authorities for the entrance of the wagon and servants, as also in other matters.

The matter of feeding so large a number with but improvized appliances and with persons inexperienced in such work, was one of great difficulty. Many of those to be served were not able themselves to perceive the difficulties inherent in the work, and expected as much as if the party consisted of but twenty or thirty. The difficulties were overcome in a measure and only the most fastidious remained dissatisfied with the commissariat. With the experience derived from this, great improvements now appear to be feasible. All however was done that was possible under the existing circumstances and considering the pecuniary limits no complaint can be reasonably made

of the fare. Messrs. Blodgett and Knapp of the Institute, attended to the purchase of the provisions and superintended the management of the dining room.

Considering the great change involved, and the experience of strangers generally in Philadelphia during the exhibition, the health of the party was exceptionally good. We were favored in having with us Dr. Sabin of Brookline, who, acting as surgeon of the expedition, was devoted in the performance of his duties, not sparing himself, treating with such skill that in most cases twenty-four hours sufficed to produce a radical cure. His pleasing, cheering, tender ways did quite as much in producing the desired results as the medical prescriptions given.

In establishing regulations for, and enforcing the discipline of the camp, it was the aim to have the minimum restriction and military work consistent with maintaining good order and securing the proper sanitary conditions necessary for the health and comfort of all. As the object of the expedition was to study the exhibition, as the change of locality, climate, water, and mode of life were in themselves trying, every effort was made to enable the students to economize their vital energies for the work in hand. The military work and display was reduced to the minimum, and in every case was made to yield to the foregoing considerations. The conduct of the students was exceptionally good and the subject of general commendation. I do not think it is possible to gather from any other college or school in the United States, so large a body of young gentlemen who would so earnestly enter into the spirit of their work, accomplish the object of the expedition and have conducted themselves with the same degree of propriety and consideration. As the members detailed for daily guard were not obliged to remain in camp, but report for duty in time to be posted on a specified relief, reliance was placed entirely on their sense of honor and duty.

The adjutant of the battalion, Mr. E. F. Williams, aided by the Sergeant Major, Mr. F. R. Loring, performed the duties of their office in the issuing of orders and making details, etc.,

most efficiently. This involved no little labor and responsibility, requiring great judgment and tact on the part of the Adjutant.

The Signal and Ordnance Officer, Mr. W. B. Bradford, aided the commandant materially as a staff officer in the execution of many details of the camp.

In the management of the camp and in the execution of all necessary regulations, efficient aid was given by the chiefs of sections, their assistants and the commissioned officers of the battalion. The following is the list of the chiefs of sections and assistant chiefs of sections, viz.:

	Chief of Section.	*Assist. C. of Section.*
Section A,	Capt. Pierce.	1st Lieut. E. C. Miller.
" B,	" I. Rich.	" L. O. Towne.
" C,	C. F. Lawton.	J. P. Gray.
" D,	T. E. Schwarz,	C. T. Main.
" E,	J. B. Gardner,	A. Austin.
" F,	W. H. Shockley,	C. A. Church.
" G,	Adjt. E. F. Williams.	

For the entertainment of the students, a piano was rented and a number of musicians were hired to play every evening. The dining room was cleared and hops were held therein. The students of the University attended bringing their lady friends. Many lady friends of the students, present in the city also attended. All this added very much to the pleasure of our students and caused a larger proportion to remain in camp at night than would have otherwise been the case. The students of the University displayed a kindly and hospitable disposition to our students, exerting themselves to add to their comfort and pleasure in many ways. In recognition of this, a reception was given to them and their friends on the night of June 21st. We were favored by the presence of a large number of ladies. The camp was illuminated and some tent floors having been placed together, out of doors, dancing took place on these and in the dining room. The camp was enlivened until after midnight by the presence of nearly twelve hundred

ladies and gentlemen. The entertainment was eminently successful as such.

On the 22d of June a number of the party left for their homes, and on the 23d the larger proportion left returning by the same route they came. Supper and breakfast were served on board the boat by servants returning to Boston with the party. They arrived in Boston somewhat fatigued but in good health and spirits, none regretting having made the trip.

As it was impossible to break up the camp at once, and it was necessary to keep up a portion of it, whilst the rest was being removed, camp equipage packed and grounds cleared, about fifty professors and students remained until June 29th and 30th. A small camping party remained until July 5th, when they finally departed.

In the preparation for the expedition and encampment, in the labors pertaining to his office as Quartermaster during the encampment, in the closing up its affairs and return of the large amount of camp equipage and other property, Mr. E. H. Gowing displayed marked ability and business capacity. The duties were laborious and difficult and their satisfactory execution deserves more than a passing notice. He was assisted by Messrs. W. B. Fisher and Jas. H. Tibbits.

To the gentlemen mentioned not connected with the encampment, thanks are due for the interest and kindness shown. I wish to express my warm appreciation of the efficient and unselfish manner in which the students occupying the various offices of the encampment performed their laborious and sometimes otherwise thankless duties. These were of such nature that in many cases the casual observer would not know of their existence nor of their real necessity and importance. Without this unselfish devotion to their duties the encampment could not have been successful; they therefore deserve the thanks of the Institute. As to the results of the expedition to the school from an educational point of view, you, Mr. President, are more capable of speaking.

The expedition to the Centennial Exhibition will undoubtedly

be considered a noteworthy event in the history of the Massachusetts Institute of Technology, and I am pleased that I should have been able to take part therein.

As this is my last report to you previous to severing my official connection with the Institute, you will pardon me for adverting to matters not within my field of work, but which I am impelled to mention by my interest in the welfare of the Institute. In my report of last year, I referred at length to the subject of physical culture, its especial necessity to students, the aid given thereby to mental culture and the great benefits derived from its introduction at Amherst College. I cannot advance any new arguments in the matter. I am most strongly convinced of its importance in all schools. Especially is it necessary at the Institute. Any time and money devoted to this, as a regular part of the curriculum of the school, will produce more than commensurate results and will add much to the future success and reputation of the school, — the spirit of earnest work which now pervades all who enter it will not so frequently reduce their physical strength — they will add to it, do more vigorous mental work and live long enough to accumulate and increase the knowledge and mental vigor necessary for the attainment of success; the Institute will be more likely to be decorated by laurels won by its Graduates. I most earnestly entreat a careful consideration of this subject, being, as it is, of such *vital* importance.

During my tour of duty at the Institute I have observed that a large number of its Graduates, without influential friends, find great difficulty in securing professional employment soon after graduation. With these especially, this is a matter of prime importance. It is always the most difficult step to get the *initial* employment. The Graduates of the Institute are so well prepared, graduation necessarily conveys with it such capacity and preparation, that no doubt can be felt as to the future of the largest proportion. The prosperity of the school is inseparable from the prosperity of its Alumni. The sooner these become prominent in the Engineering and Scientific

world, the more quickly will the Institute acquire the reputation which is its due, and the material prosperity which will be brought to it by the aid of its Alumni. It will be enabled by them to enlarge and improve its field of work and to increase its attendance.

This may be brought about primarily, by the efforts of the members of its Corporation and its Faculty, by using the influence and interest which many of them possess in the business and educational world. Secondarily and finally this work may be taken up and carried on by the Alumni Association. Each Graduate will feel it his duty to the school to endeavour to secure employment for other Graduates. No one can be so placed but that opportunities will present themselves; a strong esprit de corps will be created. They will not so often feel that their interest in the Institute closes with their immediate connection, and both the school and its students will be benefitted.

I am extremely desirous of seeing the work, which I have endeavored to shape so as to give the best results within its circumscribed limits, carried on successfully. In order that it may attain the highest degree of success possible within those limits, it is absolutely indispensable that it should receive the ungrudging, unqualified, hearty support of the Faculty. Let it be considered that the military instruction is inevitably in the Institute as a necessary part of its creation and existence — that experience has shown that it is not detrimental to its interests as a scientific school if properly managed and circumscribed — that it is desirable to make this portion of its curriculum as thorough, within its apportioned limits, as other work of the school — that it will be of benefit to the nation in the emergency of a war — that it is the desire to cause this work to be carried on in good faith with the Government — that it will be considered less a hardship by the students if they observe that the work is inevitable and it receives the hearty support of the Faculty. For these reasons, therefore, I most earnestly make the parting request not alone to accord the Military

instruction a passive but an active and generous support — that efforts be made to make it absolutely attractive to the students. A careful consideration of this subject will surely indicate that such a course is the only one open, in order to give stability to the department of military instruction, prevent its being detrimental and a source of constant irritation.

In parting from you officially let me express my appreciation of your unfaltering support and the courtesy with which I have been almost invariably treated by the members of the Corporation, Faculty and Students of the Institute, during nearly four years of duty, which necessitated, on my part, a course absolutely distasteful and obnoxious to many. Amongst the students I have found a very large proportion, who, if life is spared them, will take a high standing in any field of work which they may undertake — I have found that the general moral tone of the students, as a body and as individuals is higher than in any other school that has come under my observation. In reviewing the time spent by me at the Institute, I can not help but feel that, balancing all things, it has been both pleasant and profitable to myself. I will always feel an interest in its welfare, and will endeavor to further it and the interests of its Students and Graduates whenever the opportunities to do so can be seized.

I am Sir,

Very sincerely and respectfully,

E. L. ZALINSKI,

1st Lieut. 5th U. S. Artillery.

LOWELL DEPARTMENT OF INDUSTRIAL DESIGN, FOR 1875–76.

President J. D. Runkle: —

At the close of the fourth year of my department, I have the honor to submit to you the following report of the progress attained by my pupils. Of the entire number of graduates, twenty-four, twenty-two have received situations as designers and finishers in different mills in the New England and Middle States. During the past year the school has had two public exhibitions, one in Boston, the other in Philadelphia, at the Centennial Exhibition. At both places the exhibitions were well attended and a large and varied collection of patterns was displayed. At Philadelphia we were awarded two diplomas, one by the Women's Department; the other by the General Commissioners. The reasons assigned by the latter for their bestowal are as follows: "For the beauty, and general merit of the drawings exhibited; for their useful effect on various important industries and especially for their bearing upon technical education in general." The advanced pupils have the privilege of exhibiting their designs to manufacturers and frequently succeed in disposing of their patterns.

I would suggest the necessity of more materials as samples of the style of the season, such as novelties in oil cloths, prints, laces, cretonnes, carpets and fancy woolen goods. From these we obtain ideas of the prevalent style and thereby are enabled to suit the market. At present we have only the sample patches from Claude Frères of Paris. After long exertions I have succeeded in obtaining a loom, on which I propose to

teach weaving to my pupils. By the aid of the loom, I am enabled to supply a deficiency which has long existed in my department; I can now furnish designers for silk and woolen goods. Without a loom such a thing is impossible; as a designer for silk and woolen goods must thoroughly understand weaving, and the art of putting a design on the loom. During the last few months I have introduced ceramic painting and the decoration of pottery; the young ladies are much interested, and bid fair to make a gratifying success in this branch of art. The following is a list of the pupils in situations, and the place of employment of each.

James L. Folsom . .	Hartford Carpet Co., Thomsonville, Conn.
Alex. Johnston . . .	Pacific Mills, Lawrence.
Sam'l Hudson . . .	" " "
Everett Authes . . .	Manchester Print Co., Boston.
Mary Jefferson . . .	" " " "
Elizabeth Mendum . .	" " " "
Carroll S. Faunce . .	Hamilton Woolen Co., New York.
Chas. H. Cowdrey . .	Oriental Print Co., Boston.
William Schroeder . .	" " " "
Howard G. Hinckley . .	Merrimac Print Co., Boston.
S. R. Eaton . . .	" " " "
Edgar Eames . . .	" " " "
Minnie Ricker . . .	Hamilton Print Co., Boston.
Harriet A. Parker . .	Roxbury Carpet Co., "
Henry P. Mabille . .	American Print Co., New York.
Annie D. Stimers . .	Sprague Print Co., " "
John H. Tarbell . . .	Donnell Manufac. Co. " "
Kate T. Simonds . . .	David Browne & Co., Philadelphia.
Edward Williams . .	Lithographer, Boston.
Henry Morse . . .	Carpet Mills, Maine.
Ernest Pierce . . .	Pacific Mills.

Respectfully submitted,

CHARLES KASTNER,

Director.

DEPARTMENT OF ARCHITECTURE.

President Runkle,

DEAR SIR: — The department under my charge was fully described in your Report for the year 1875, and but little change has since taken place in it. The only unusual event during the year 1876 has been the exhibition of the work of its students at the International Exhibition at Philadelphia. No drawings were made expressly to be exhibited, the instruction following its usual course, but in addition to those made by students still in the school a certain number were obtained from students of previous years, so that we were able to make a very fair presentation of the work of the Department. The result was unexpectedly satisfactory, and the drawings attracted a great deal of favorable attention especially on the part of visitors from abroad. They were quite unlike anything else in the Exhibition, the American schools not undertaking to cover the ground that we go over, and the foreign schools of similar grade not exhibiting their work. Towards the close of the Exhibition the American Institute of Architects held its annual Convention in Philadelphia, and a valuable opportunity was thus offered of making known to the profession the real issue of our undertakings. At about the same time information was received from Col. J. J. Marin, Commissioner from the King of Spain, that the splendid collection of casts of Moorish and Spanish architectural detail which formed a chief point of interest in the Spanish Pavilion was to be distributed among the educational museums in different parts of the country, and that in addition to those sent to the Museum of Fine Arts in Boston a portion of them would be sent to augment our own collections.

After the close of the Exhibition, accordingly, about fifty pieces of Saracenic and Renaissance detail were delivered to our agent in Philadelphia and are now hung upon our walls. Col. Marin was also good enough to accede to my suggestion, and send us a very interesting set of drawings made in the Municipal Schools of Madrid. At the same time we received from the agents of MM. Dûcher et Cie, of Paris, through M. Albert Levy of New York, six screens, covered with examples of their architectural publications, of great interest and value, and from Messrs. Galloway & Graff, of Philadelphia, a large vase in red terra-cotta, from an original in the British Museum.

Almost all the students then belonging to the Department, with as many as a dozen former students, joined the expedition organized by the authorities of the Institute and encamped for a fortnight on the grounds of the University of Pennsylvania. The points of professional interest proved too numerous to admit of systematic study during so short a period, and in respect of tangible results the undertaking so far as concerns this Department disappointed my expectations. But it was none the less a success, and the young men found that although they had not much to report in regard to the special topics assigned to each, it saved them from wasting time to have their attention thus definitely fixed upon special points of real interest.

Besides the gifts above mentioned a number of volumes of professional interest have been received from Mr. Geo. B. Emerson, from Mr. E. C. Cabot, and from Mr. G. J. F. Bryant, and the Royal Institute of British Architects in London and the Société Centrale des Architectes in Paris continue regularly to send us their publications. We are also indebted to Messrs. Hartwell & Swasey for a large and interesting model of a church erected by them at Fall River. No other important additions have been made to the library or collections, but a good deal of work has been done in re-arranging and cataloguing, and in binding and re-binding books, and the number of diagrams used in the lectures has been considerably increased.

The collections, though thus deficient in new material and

without the means of supplying old deficiencies which become daily more apparent, prove more and more serviceable as the work of the department is so adjusted as to bring them into more constant use. As their character and value become better known in the community and as interest in such subjects increases, their range of service becomes every year more extended, the books, drawings and photographs being freely lent to responsible persons when this can be done without inconvenience to ourselves.

But in this respect as in every other the usefulness of the department is greatly impeded by the limitation of its resources.

The number of students, both Regular and Special, has been larger than ever before and of better quality, the two years Special Course affording opportunities for young men who have already had an office training to come and get the training that an architect's office cannot give, of which an increasing number of such students from various parts of the country show a disposition to avail themselves.

I am, very respectfully, yours,

WILLIAM R. WARE.

MINING EXPEDITION TO PENNSYLVANIA.

President Runkle,

DEAR SIR: —Though the long study of the Centennial Exhibition had made considerable drafts on our time, strength, and money, it seemed advisable that the mining students, before our return to Boston, should take advantage of our nearness to the anthracite region and spend another week in seeing something of the great mineral resources of Pennsylvania *in situ*. Accordingly we made up a party of thirteen, of the classes of 1876 and 1877. Arranging for some to join us on the way, ten of us started early Monday morning, June 26th, by the North Pennsylvania Railway, and arrived betimes at the busy town of Bethlehem. Here a walk of some four miles, under a blazing mid-day sun, brought us to the Bethlehem zinc mine, noted for being drained by one of the most powerful pumping engines in the world. The mine itself is of a remarkable character and its irregular veins were yielding a good supply of very compact blende. But the huge engine had to be kept in unceasing motion to render the deposits accessible, and the cost of working had become too great as compared with the contract price of New Jersey zinc ore, and not long after our visit the mine was closed not to be reopened probably for a generation to come. So it seems we had improved almost the last opportunity to go through the intricate, dripping passages of the Bethlehem zinc mine. Returning to a very late dinner in town we afterwards spent some time in the extensive zinc

smelting works and took up the rest of the long day in watching two "blows" of Bessemer iron in the immense and well appointed works of the Bethlehem Iron Company.

A night ride brought us to the closely hemmed in town of Mauch Chunk, with its never ending rumble of coal trains. Tuesday morning we found our way to the romantic Glen Onoko all aglow with its lavish profusion of wild rhododendron flowers. Here was scenery that might well stir the hearts of even such delvers in the earth as ourselves, and when we had scaled the heights above and were enjoying the broad view from Lookout Point it was resolved, in our by no means temporary enthusiasm, that a visit to Glen Onoko may make an entirely proper and legitimate part of a mining excursion. The returning train brought us back to Mauch Chunk in time for a forenoon trip up the famous Switch Back railway to Summit station. We took a half mile walk along the surface debris of the burning coal mine and crawled down into one opening far enough to find an ice pavement. Little indication was there of the combustion which has been going on for years, except one or two very faint vents of vapor through cracks at the surface of the ground. When dinner was over we had to hurry a mile down hill, baggage in hand, to catch the train for Tamaqua. At dusk we found good quarters in Pottsville, and while waiting for the arrival of the rest of our party from Philadelphia some of us visited the only blast furnace then at work in town.

The next day we joined the excursion party of the American Institute of Mining Engineers, and enjoyed a rare opportunity of seeing the best parts of the anthracite region. Leaving the excursionists at Reading we waited some time for the westward train, and reached Harrisburg soon enough to have some four hours' sleep before a very early start for Johnstown. So the ascent of the Alleghanies and the ride around Horse Shoe Bend was made by daylight after a breakfast at Altoona, and our westward destination was reached before noon. Johnstown proved a much more comfortable place than the dingy aspect of

things there would lead one to expect. We were very courteously received at the extensive works of the Cambria Iron Company, which were in full operation, turning out two thousand tons of rails per week, notwithstanding the great depression in the iron business. But with coal and iron ore on the spot and each costing, ready for use, considerably less than a dollar a ton, this Company may well defy competition. Here was a fine chance to study in one compact area several three foot semi-bituminous coal seams, a thirty inch deposit of iron carbonate, the wholesale roasting of the ore, the manufacture of fire bricks, coal washing, the skilfully planned coke kilns with steam discharging-ram, blast furnaces, puddling furnaces, rail mills, and Bessemer converters, running day and night. Mr. Fulton, the engineer of the Company, devoted his whole time to us for a day, and having studied his work as an investigator was able to give us much new information at first hand. Crouched down in mine cars we had a lively two mile ride underground through the horizontal upper coal seam, and another through the ore bed. We are much indebted to the Superintendent and his several assistants for their kind attention and hearty aid during our very instructive and pleasant two days' stay.

More time might have been well spent, but it was possible, by starting homeward Friday night, to reach Boston before the national holiday and avoid the extraordinary rush of travel to the grand centennial celebration in Philadelphia. As it was, we could not all secure seats in the cars till some of our fellow passengers got out at Cresson Springs. We reached the old camping ground, where a few tents were still standing, in season for breakfast Saturday morning. Here the party was resolved into individuals, some staying longer in Philadelphia, some going on at once to New York, some taking another look at the Exhibition before embarking in the noon train for home. The approaching fourth of July had caused us to crowd a proper fortnight's work into six days, but after a few days' rest I believe no one felt the worse for our flying trip.

I must not close without grateful mention of assistance rendered by Mr. Felton and Mr. Gowen, whereby transportation on the Pennsylvania Central and Reading railroads was secured on the most favorable terms.

Respectfully yours,

JOHN M ORDWAY.

APPENDIX.

CENTENNIAL CATALOGUE.

THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY exhibits:—

1. Two Photographs of its Buildings, in Boylston Street, Boston, and twenty Photographs of the principal lecture-rooms and laboratories.
2. A complete set of printed documents describing its work.
3. A set of elementary Drawings made by students of the First Year in portfolios.
4. Drawings of students in the Department of Civil Engineering, framed and in portfolios.
5. Drawings of students in the Department of Mechanical Engineering, framed and in portfolios.
6. Drawings and Designs of students in the Department of Architecture, framed.
7. Drawings, Models and Samples, illustrating the professional work in the Department of Mining and Metallurgy.
8. Models, Instruments and Papers, illustrating the professional work in the Department of Physics.
9. Drawings and Designs made by pupils in the Lowell Free School of Industrial Design.
10. Graduating Theses in the Departments of Civil, Mechanical and Mining Engineering, Architecture, Physics, Chemistry, Natural History, Science and Literature, and Philosophy.

The exhibition consists entirely of work done in the school, and the apparatus of instruction is not exhibited except so far as it has been devised or made by professors or students.

THE DEPARTMENT OF CIVIL ENGINEERING exhibits:—

I. Sixteen framed drawings.

II. Ninety drawings in portfolios.

The subjects of these Drawings embrace Railroad Surveys, Topography, Stone Cutting, Bridge and Roof Construction, and Original Designs for Structures.

III. Thirteen theses by members of the class graduating this year, as follows:—

1. The Providence, R. I., Water Works, by Thomas Aspinwall, Jr., Brookline, Mass.
2. The Merrimac River Bridge, at Nashua, N. H., by Thomas W. Baldwin, Bangor, Me.
3. The West Chester Park Bridge in Boston, by Joshua B. F. Breed, Louisville, Ky.
4. A Review of the Buffalo Water Supply, by Harry T. Buttolph, Buffalo, N. Y.
5. The Front Street Bridge in Worcester, Mass., by Frederick K. Copeland, Fairhaven, Vt.
6. The Broadway Bridge in Boston, by John R. Freeman, W. Bridgton, Me.
7. The Superstructure of the East River Suspension Bridge in New York, by Martin Gay, Staten Island, N. Y.
8. The Albany Street Bridge in Boston, by Frederick W. Hodgdon, Arlington, Mass.
9. The Iron Bridge over the Merrimac River at Tyngsboro', Mass., by Arthur L. Mills, Everett, Mass.
10. Design for a Wrought Iron Post Truss, by Henry Raeder, Hyde Park, Mass.
11. Draw in the West Boston Bridge, by C. Leon Rich, Morristown, Vt.
12. The Eastern Avenue Swing Bridge in Boston, by Henry M. Waitt, Nantucket, Mass.
13. A Highway Bridge at Haverhill, Mass., by Henry B. Wood, Woburn, Mass.

The Department of Mechanical Engineering exhibits:—

I. Four hundred and thirteen drawings and tracings framed and in portfolios, as follows:—

Boilers.

1–21	A Martin Boiler.	4 Drawings, 17 Tracings.
22–25	Boiler of Providence Pumping Engine.	4 Tracings.
26–28	Boiler of Monitor Nahant.	3 Tracings.
29–30	High Pressure Marine Boiler.	2 Tracings.
31–45	Cunningham Stationary Boiler.	15 Drawings.

Stationary Engines.

46–82	Harris Corliss Engine, Elevation.	2 Drawings.
	" " " Details.	12 Drawings, 5 Tracings.

83–85	18 HP. High Pressure Engine.	1 Drawing, 2 Tracings.
86	Beam Engine.	1 Drawing.
87–90	Steam Cylinder and Valve.	2 Drawings, 2 Tracings.
Marine Engines.		
91–94	Beam Engine.	4 Tracings.
95–100	Engine of Steamer Humboldt.	6 Tracings.
101–109	Launch Engine.	6 Drawings, 1 Tracing.
110	Marine Engine.	1 Drawing.
Locomotive Engines.		
111–160	Elevation and Details.	9 Drawings, 41 Tracings
Steam Pumps and Pumping Engines.		
161–169	Blake, Lawrence and other Pumps and Pumping Engines.	9 Tracings.
Hydraulic Machinery.		
170–175	Cranes and Presses.	5 Drawings, 1 Tracing.
Water Motors.		
176–186	Turbines and Breast Wheels.	2 Drawings, 9 Tracings.
Screw Propellers.		
187–193	Various examples.	17 Tracings.
Machine Tools, etc.		
194–197	Upright Drill.	4 Drawings.
198	Boring Machine.	1 Drawing.
199–206	Car-axle Turning Lathe.	8 Drawings.
207, 208	Steam Hammer.	2 Tracings.
209	Steam Derrick.	1 Drawing.
211, 212	Section of Mill.	2 Drawings.
213–219	Stub End.	7 Drawings.
220–222	Cross Head.	3 Drawings.
223–226	Eccentric.	2 Drawings, 1 Tracing.
227–251	Screws, Cams, Cranks, etc.	24 Drawings.
252–265	Driving Pulley. Boott Mills.	14 Drawings.
Toothed Wheels and their Construction.		
266–280	Sector Gears.	15 Drawings.
281–294	Bevels.	14 Drawings.
295–337	Gear Templets.	43 Drawings.
338–341	Sector Gears.	4 Drawings.
342–359	Bevel Gears.	18 Drawings.
360, 361	Gear Teeth.	2 Drawings.
362–370	Rolled Curves.	9 Drawings.
371–382	Course in Gear Construction.	12 Drawings.
383–389	Gear Templets.	7 Drawings.
390–413	Spur Gears.	23 Drawings, of which seven are designs.

These Drawings are not exhibited as evidences of skill in Draughtsmanship, but as graphical reports of some of the information which the Students acquire during their professional course. They are the work of Students, and are about half the drawings made by them during the year.

II. Seven Theses by the Graduating Class.

1. Locomotive Engineering, by Francis E. Galloupe, Lynn, Mass.
2. Steam Boilers, by Clarence L. Dennett, Beverly, Mass.
3. Screw Propellers, by Charles F. Prichard, Marblehead, Mass.
4. The Efficiency of Marine Engines, by Charles T. Main, Marblehead, Mass.
5. Design for a Mechanical Laboratory, by Aaron D. Blodgett, Boston, Mass.
6. Shafting and its Fittings, by Theodore J. Lewis, Philadelphia, Pa.
7. Paper Mills and Machinery, by Sumner Hollingsworth, South Braintree, Mass.

The Department of Architecture exhibits 77 drawings in 60 frames, illustrating the instruction in Architectural Drawing and Design. These drawings are the work of the regular and special students during the last year and a half, and comprise about a tenth part of similar drawings made during that time by about fifty different students.

1. The Drawings numbered 1 to 5 show the Elementary Work taken up at the beginning of the Course. Every student does similar work to this, or its equivalent.

2. The Drawings numbered 6 to 11 are exercises in Architectural Drawing, being fac-simile copies of original drawings, made in the *Ecole des Beaux-Arts*, in Paris, now in possession of the Department.

3. The Drawings "from prints" numbered 12 to 19, involve more independent work than the foregoing, the originals being in most cases small line drawings, without shading or color.

4. The Drawings numbered 20 to 24, are made from free-hand sketches of buildings in Boston, generally without exact measurements. This work is done by the more advanced class.

The work already mentioned is mostly done during the months of October and November, at the beginning of the school year.

The six remaining months, from December to May inclusive, are mostly occupied with a series of architectural problems, made in accordance with written programmes, specimens of which are given.

The subjects of these drawings are: —

1, A Porch; 2, A Campanile; 3, A Summer House; 4, A Pavilion between two Bridges; 5, A Billiard Room and Boat House; 6, The Employment of Six Columns; 7, A Temple Tomb; 8, A Staircase under a Vault

or Dome; 9, The Restoration of a Pompeiian House; 10, A Lamp Post; 11, A Fountain; 12, A Memorial Library; 13, A Memorial School House; 14, A Railroad Station; 15, An Artist's House; 16, A Catholic Church; 17, Water-Works in a Park; 18, A Dwelling House; 19, A Farm Barn; 20, A School of Architecture.

5. The rest of the drawings, numbered 25 to 60, illustrate this work.

This Department exhibits two Graduating Theses, illustrated by drawings.

1. A Railroad Station upon a Bridge, by William B. Dowse, of Boston, Mass.

2. Reservoir and Water Works in a Park, by Amos J. Boyden, of Foxboro', Mass.

THE DEPARTMENT OF MINING AND METALLURGY exhibits:

1. Two Sketches of the Mining Laboratory.
2. Two Sketches of the Metallurgical Laboratory.
3. A Novel Assay Ore Dresser.
4. A set of Samples of work done by this Ore Dresser.
5. A Tabular Statement of the System of Ore Dressing used at the Institute.
6. A set of Samples taken from the working of a ton of Ore with the Mining Machinery in the Laboratory.
7. Specimen of Lead from the Practical Treatment of an Argentiferous Lead Ore from Burleigh Tunnel, Colorado, extracted by S. James, Jr., in the Metallurgical Laboratory, from 1100 lbs. of ore.
8. Specimens of Lead from the Practical Treatment of an Argentiferous Lead Ore from the Merrimac Mine, Newburyport, Mass., extracted by W. D. Townsend and Julius H. Susmann, in the Metallurgical Laboratory, from 784 lbs. of the ore.

Six Graduating Theses.

1. The Newburyport Silver Lead Mine, by J. H. Susmann and W. D. Townsend, Boston.
2. The Richmond Blast Furnace, by Thomas W. Robinson, Chicago, Ill.
3. A Report on the Vershire, Vt., Copper Mine and Ore, by R. H. Gould, East Cambridge.
4. The Port Henry Iron Foundry, by C. F. Allen, Cincinnati, O.
5. The Metallurgical Treatment of an Argentiferous Galena from Burleigh Tunnel, Colorado, by S. James, Jr., Cambridgeport, Mass.
6. An Investigation and Report on the Pomeroy Iron Works at West Stockbridge, Mass., by Theo. E. Schwarz, Boston.

THE DEPARTMENT OF CHEMISTRY exhibits:

Five Theses of the Graduating Class.

1. Anthracene, a Coal-Tar Product, by Charles R. Fletcher, Chelsea, Mass.
2. The Action of Chloride of Sulphur upon Spirits of Turpentine, by Albert H. Low, of Chelsea, Mass., and Charles N. Waite, of Medford, Mass.
3. The Action of Tungstic Acid upon Gelatin, by W. P. Atwood, Lowell, Mass.
4. A Practical estimation of the Value of Tanning Materials, together with Points on Tanning, by Wm. E. Nickerson, Somerville, Mass.
5. The Determination of Oxygen in Organic Bodies, by Charles C. R. Fish, Cambridgeport, Mass.

THE DEPARTMENT OF PHYSICS exhibits:

I. *Experiments.*

1. Estimating Tenths.
14. Spherometer.
72. Polarized Light.

These experiments are selected from a list of two hundred, and are performed by students in classes of twenty or thirty.

The apparatus is simple, inexpensive, and not easily injured.

II. *Work done by students.*

1. Curves showing the results of the above experiments.

When two nearly coinciding are given, one is obtained by calculation, the other by actual measurement.

2. Photographs taken by students.
3. Simple Truss Bridge, built by students.
4. Arch Bridge, planned, built, tested and reported upon by E. Holbrook, student.
5. Draw-bridge, planned, built, tested and reported by C. D. Austin and W. T. Blunt, students.

III. *Novelties and Inventions.*

1. Polarimeter, to measure the amount of polarization in a beam of light. Invented by E. C. Pickering.
2. Simple apparatus for drawing Lissajous' curves. Invented by E. C. Pickering.
3. Wind Vane. Invented by W. H. Pickering, student.

4. Micrometer Level, and Mountain Stadia, to determine the height and distance of a distant mountain. Invented by E. C. Pickering.
5. Balance, in which the object to be weighed and the weights are successively placed in the same scale. Invented by E. C. Pickering.
6. Dividing Engine. A cheap and accurate instrument for constructing scales of equal parts. Invented by E. C. Pickering.
7. Plane Table. Invented by E. C. Pickering.
8. Cosine Galvanometer.
9. Simple Galvanometer.
10. Phonautograph Curves, drawn by C. F. Morey, student.
11. Daylight Photometer, made by Charles H. Williams, student.
12. Results of experiments made by students on saving heat by different ways of covering steam pipes.
13. Resistance Coils, made and adjusted by students.
14. Published Memoirs, by students.
15. Text Books.
16. Examination Papers on Lectures.

IV. *Three Theses by the Graduating Class.*

1. The Atomic Theory as applied to Gases, with some Experiments on the Viscosity of Air, by Silas W. Holman, Framingham, Mass.
2. New Experiments in Sound, by William W. Jaques, of Newburyport, Mass.
3. On the Mean Specific Gravity of the Earth, by J. B. Henck, Jr., of Brookline, Mass.

The Department of Natural History exhibits:

Two Theses by the Graduating Class.

1. Geology of Eastern Massachusetts, with a Map, by W. O. Crosby, Georgetown, Col.
2. Catalogue of the Alcidæ contained in the Museum of the Boston Society of Natural History, with a Review and proposed Classification of the Family, by W. B. Barrows, of Reading, Mass.

The Department of Science and Literature exhibits:

Three Theses by the Graduating Class.

1. The Kingdom of Italy, by W. E. Davis, of San Francisco, Cal.
2. The Times of Edward the Third, by Charles H. Heustis of Hyde Park, Mass.
3. The British Provinces of Australia, by Charles A. Sawyer, of Chicago, Ill.

THE DEPARTMENT OF PHILOSOPHY exhibits:

Two Theses by the Graduating Class.

1. Kant's Æsthetic: A Re-statement of it, with some Critical Queries, by David W. Phipps, Boston, Mass.
2. Historical and Logical Relations between Fichte and Kant, by R. C. Ware, Marblehead, Mass.

THE LOWELL SCHOOL OF PRACTICAL DESIGN exhibits seventy-seven designs in thirty-seven frames, the work of its male pupils. The work of the female pupils is exhibited in the Women's Pavilion.

CATALOGUE OF MATERIAL

COLLECTED AT

THE CENTENNIAL EXHIBITION OF 1876.

CONTENTS.

DEPARTMENT I. — EDUCATION AND SCIENCE.

Class.

1. Books and Pamphlets for the General Library.
2. " " " " Department of Civil Engineering.
3. " " " " " Mechanical Engineering
4. " " " " " Mining Engineering.
5. " " " " " Architecture.
5½. " " " " " Physics.
6. Articles constructed from Wood and Iron for purposes of Instruction.

DEPARTMENT II. — AGRICULTURE.

FOREST PRODUCTS.

7. Timber and useful Woods.

TEXTILE SUBSTANCES OF ANIMAL OR VEGETABLE ORIGIN.

8. Wool, washed and unwashed.
9. Hair, Bristles, &c.
10. Silk in the cocoon and reeled.
11. Cotton on the stem, in the ball, and ginned; also Cotton and Fibre Seeds.

AGRICULTURAL PRODUCTS.

12. Cereals, (Wheat, Rye, Oats, &c.,) with their products.
13. Plants used for Food other than Cereals, (Peas, Beans, &c.)
14. Nuts.
15. Fleshy Fruits, (Dates, Apricots, &c.)
16. Thein Plants, (Tea, Coffee, Cocoa, &c.)
17. Sacharine Seeds and substances.
18. Aromatics, (Anise, Dill, &c.)

19. Oleagineous Seeds, (Flax, Rape, Dill, &c.)
20. Forage Plants, (Clover, Hay, &c.)
21. Gums and Resins.
22. Medicinal Plants.
23. Miscellaneous Seeds and Plants.

DEPARTMENT III.—MINING AND METALLURGY.

MINERALS, ORES, BUILDING STONES AND MINING PRODUCTS.

24. Mineral Combustibles, (Coals, &c.)
25. Clays, Kaolin, Silex, &c., Earths, and Refractory Stones for Furnace Linings.
26. Limes, Cements, both raw and burned, accompanied by specimens of the crude rock or material used. Also Artificial Stone, Concrete, &c.
27. Iron Specimens in the Pig and Rolled Bar.
28. Collection of Ores and Associated Minerals.

METALLURGICAL PRODUCTS.

29. Lead and Silver, (the result of extractive processes).

DEPARTMENT IV.—MANUFACTURES.

YARNS AND WOVEN GOODS.

30. Cotton Sheeting and Shirting, plain and twilled.
31. Coarse Fabrics of Bark, Grass, &c.
32. Woolen and Mixed Fabrics, Yarns, &c.

METALLIC PRODUCTS.

33. Telegraphic Wires and Specimens of the Insulating Materials in both the Crude and Manufactured states.
34. Specimens of Nails, Tacks, &c.
35. Files and Hardware.

CHEMICAL PRODUCTS, CERAMICS, POTTERY, ETC.

36. Bricks, Drain Tiles, &c.
37. Fire Clay Goods, (Crucibles, Pots, &c.)
38. Tiles, plain, enamelled and encaustic; also for pavements, roofing, &c.
39. Porcelain and Pottery.

DEPARTMENT I.

CLASS 1. BOOKS AND PAMPHLETS FOR THE GENERAL LIBRARY.

169. Abernethy, Alonzo. School Laws of Iowa.
72. American Museum, N. Y. 1st Annual Report, 1870.
73. " " " 2d " " 1871.
74. " " " 3d and 4th " 1872.
75. " " " 5th and 6th " 1874.
76. " " " 7th " 1875.
71. American Museum, N. Y., ceremonies at laying of corner stone, 1874.
5. Argentine Republic. Centennial Catalogue of the Argentine Section.
14. Austria. Katalog. der Osterreichischen Abtheilung.
135. Bankers Building (Centennial Grounds). Report of Opening of Building.
136. Barcena, Mariano. Certain Mexican Meteors.
24. " " The Rocks known as Mexican Onyx, (2 copies.)
11. Belgique. Catalogue des produits industriels et des Œuvres D'Art, (4 copies).
7. Belgium. Catalogue des Œuvres D'Art, (3 copies).
118. Belgium. Construction et Ameublement de Batiments D'Ecole.
94. Bitterlin, Paul et Fils. Catalogue of Publications.
204. Boston College Catalogue, 1874–75.
155. School of Modern Languages, Boston. Report.
107. Brazil. Agricultural Industries for Emigrants.
35. " Archivos do Museu Nacional.
101. " Catalogo da Exposiçao Nacional em 1875.
36. " Descripçao Topographica do Mappa da provincia de Santa Catharina.
19. " Estudos sobre A Quarta Exposiçao Nacional de 1875.
102. " Relatorio sobre a pretendida enxertia da canna de assucar, 1876.
34. " Revista de Horticultura.
33. " Subsidies to the formation of the physical map of Brazil.
21. " Supplement No. 1 to Brazilian Catalogue.
27. " Special Catalogue of the Brazilian Section.
98. " The Empire at the Universal Exhibition, 1876.
99. " " " (German)
100. " " " (French)
13. " The Maté of Parana.
20. " Trabalhos Historicos Geographicos. E. Hydrographicos.
198. Brewers' Industrial Exhibition 1876. Essays on the Malt Liquor Question.
53. Buist & Co., Phila. Catalogue and Garden Manual.
124. Canada. Catalogue of Educational Exhibit.
87. " Catalogue of Exhibitors.
134. " Council of Arts and Manufactures.
79. " Descriptive catalogue of Economic minerals.
59. " Educational Institutions of the Province of Ontario.
57. " Information for intending emigrants.
64. " Province of Ontario, Annual Report of Commissioners on Agriculture and Arts.
208. " Rapport sur le service de l'Asile d'Alienes de Quebec.
125. " Report of Fruit Grower's Association of Ontario.

91. Canada. Report of the Select Committee on Immigration and Colonization.
92. " Report of the Surveyor General of Dominion Lands.
209. Carlisle, Henry C. Sixth annual report of the Trade, Commerce, Railroads of Indianapolis.
2. Catalogue du cercle de la librarie de l'imprimerie.
187. Charlestown. Report of the Sect. of Infant-schools.
226. Charpentier, —. Catalogue de la Bibleothèque-Charpentier.
152. Chauncy Hall School. Catalogue.
31. Chicago. Course of study for Public Schools.
97. " Twenty-first Annual Report of Board of Education.
170. Chili. Catalogue of Centennial Exhibit.
171. " " " " in Portuguese.
17. China. Catalogue of the Chinese Section.
189. Christern, F. W. Catalogue of Standard French Books.
220. Clarke Institution. Teaching the Deaf by Articulation.
150. " J. L. History of the Massachusetts Insurance Department.
126. Coldwater. Address to the State Public School.
115. College of Holy Cross. Historical Sketch.
232. Cone, Wm. R. (et. als.). Anniversary of the Retreat for the Insane at Hartford, Connecticut.
143. Connecticut. Hospital for the Insane. Report of the Board of Trustees.
233. " " " Tenth Annual Report.
231. " State Reform School. Twenty-Fourth Annual Report, 1876.
23. Creswell, F. Australia. List of Seeds.
200. Crosby, W. O. Report on the Geological Map of Massachusetts.
189. Deer Island, (Boston Harbor). Pauper Boys School.
190. Delagrave, Ch. Extrait du Catalogue Général de la Librairie.
186. Delahaye, V. Adrien et Cie. Catalogue des Livres de Fonds.
9. Denmark. Catalogue of Danish Section.
144. Doulton Stone-ware and Lambeth Faience.
225. Ducroro, —. Catalogue of the Ducroro Library.
210. Dufferin, Lord. "Canada the place for the Emigrant."
80. Dumaine, J. Catalogue de la Librarie Militaire.
179. Empire Transportation Co. Statements, etc.
236. Fialho, Aufriso. "Dom Pedro II, Emperor of Brazil."
84. Foote, A. E. Catalogue of Minerals.
39. France. Catalogue des ouvrages de Géographie et de Topographie de Institut Géographique de Paris.
85. Germany. Catalogue of Exhibit of Chemical Industry.
4. " Catalogue of German Section.
123. " Der Buchhandel und Die Graphischen künste Deutschlands.
175. Giovanni Boucenelli e Figli. The Manufacture of Mosaics.
203. Grafton High School. Catalogue, 1875–6.
Great Britain. Catalogue of British Section.
86. Guillaumin et Cie. Catalogue.
172. Hawaii. Statistics and Information.
47. " Hawaiian Guide Book.
153. Heard, J. C. Report of the Russian Ministry of War.
221. Henderson, Howard, A. M. Exhibit of Kentucky's Educational System and Institutions.

222. Henry, James P. Resources of the State of Arkansas.
191. Hetzel, J. & Co. Catalogue of Publications.
141. Highland Military Academy. Report.
118. Holidaysburg Seminary. Catalogue of Officers and Students.
215. Holland. The Artisan's School in Rotterdam.
164. Howard, B. Frank Annual Report of the Pork Packing of the West.
206. Illinois Industrial University. Catalogue, 1875–6.
51. " Report of the Railroad and Warehouse Commission, 1875.
63. " School Report, 1873–4.
37. India. Descriptive Catalogue of Indian Section.
111. Indiana. Agricultural Report, 1875.
112. " Geological Survey, 1875. Cox, E. T.
107. " Institute for the Blind. Twentieth Annual Report.
108. " New school law, and report of the Supt. of Public Instruction, 1872–3–4.
109. " Twentieth report of the Supt. of Public Instruction.
110. " Twenty-second " " " " "
89. " Twenty-third " " " " " 1875.
45. Iowa. State Facts.
18. Italy. Catalogo degli Expositori Italiani.
48. Japan. Catalogue of Imperial University of Tokio.
30. " Catalogue of Japanese Section.
49. " Report of the Minister of Education, 1873.
65. Kansas. Agricultural Report, 1875. (2 copies.)
82. Kuhn, B. The Farmers Friend.
228. Laboulaye, M. Ch. Dictionnaire des Arts et Manufactures et de l'Agriculture.
120. Lafayette College. Catalogue of Officers and Students.
140. Lasell Seminary. History and Description.
117. Lehigh University. Catalogue of Officers and Students.
223. Lévy Nuchel. Catalogue of Publications.
229. Lovues, Henri. Catalogue de la Librairie Renouard.
184. Lowell, Mass. Fiftieth Annual Report of School Committee, 1875.
106. Maryland. Report of the Commissioners of Fisheries.
159. Massachusetts. Catalogue of Educational Exhibit.
219. " Catalogue of Exhibit of Industrial Drawing and Modelling.
158. " Educational Institutions, 1876.
147. " Report of the Supt. of the School for Feeble Minded Youth.
148. " State Board of Health. First Annual Report.
149. " State Library. Report of the Librarian.
160. " Tenth Annual Report on Inland Fisheries.
227. Massen, G. Catalogue général de l'Académie de Médecine.
56. Maury, M. F. Resources of West Virginia.
127. Mayhew, Ira. Statement and Exhibit of Business College work.
52. Meme, Alfred & Sons. Catalogue of Publications.
67. Meteorological Observatory, N. Y. Report of the Director, 1871.
66. " " " " " " 1872.
68. " " " " " " 1873.
70. " " " " " " 1874–5.
213. Meyer, Heiur – Ad. – "Ivory."
32. Mexico. Catalogue de la colleccion de Productos Naturales Indigenas.
10. " " of Mexican Section. (3 copies.)

128. Michigan. Chart and Key of the Educational System.
129. " Sketches of its Resources and Industries.
130. " Historical Sketch of the University of Michigan.
131. " Calendar " " " "
132. " Second Annual Report of the Board of Control of the State Public Schools.
133. " Catalogue of Centennial Exhibit.
42. State Catalogue.
156. Montreal. Report of Fruit Committee of Agricultural and Horticultural Society, 1876.
217. Moore, J. G. & Co. Creosoting by the Bethel Process.
193. Moreira, Nicolau, J., M. D. Brazilian Coffee.
192. " " " " Note on Brazilian Vegetable Fibres.
188. Morel et Cie. Catalogue de la Librairie Morel.
58. Mount Holyoke Seminary. Historical Sketch.
181. Munday, E. H. The Proof Sheet.
29. Netherlands. Catalogue of Booksellers Association.
1. " Collection of the Treasury Department.
78. " " " " "
66. " Elementary and Middle Class Instruction.
55. New Brunswick. Catalogue and Report on the Woods and Minerals.
196. New Jersey. Catalogue of the Centennial Exhibit of the Geological Survey.
6. New South Wales. Catalogue of Centennial Exhibit.
211. " " " Its Progress and Resources.
212. " " " Mineral map and general statistics.
161. " " " " " " " "
40. Newspapers. Catalogue of American Newspapers, 1876.
151. Newton. Report of Public Schools.
28. Norway. Norwegian Special Catalogue.
201. Nowell, Edwin C. Paper on the Local Industries of Tasmania.
12. Pennsylvania. Catalogue of Educational Exhibit.
122. " Common School Laws.
50. " School Report, 1875.
104. " " " "
8. Perthes, Justus. Verlags Catalog.
214. Peter, Robert, M. D. Hemp Culture in Kentucky.
121. Philadelphia Institution for the Feeble Minded. Catalogue of Exhibit.
26. Philippine Islands. Catálogo General. (3 copies.)
180. " " Catalogue of Forestal products exhibited at the Centennial Exhibition, 1876.
230. Pickering, T. R. Connecticut at the International Exhibition.
138. Pittsfield High School. Statistics, etc.
224. Plon, E. & Cie. Catalogue of Publications.
168. Polytechnic Review. May 10th, 1876.
178. Proctor, J. R. General account of the Commonwealth of Kentucky.
216. Quebec Lunatic Asylum. Report of the Superintendent, 1875.
81. Randolph, Chas. Eighteenth report of the Trade and Commerce of Chicago.
163. Rensselaer. Polytechnic Institute. Annual Register, 1876.
62. " " " Publications. Troy, N. Y.
218. Russell, E. Harlow. State Normal School at Worcester, Mass.

154. Russia. Catalogue of Exhibit of Fossils.
16. " Catalogue of Mining Department of the Ministry of Crown Domains.
8. " Catalogue of Russian Section. (2 copies.)
46. " Catalogue of School Apparatus, etc. Pedagogic Museum.
194. Saldanah da Gama, José, Ph.D. Notes on Textile Plants of Brazil.
195. " " " Products of the Brazilian Forests. Catalogue.
15. Schröder, J. Catalogue and price list of Schröder's Models.
96. Scribner, Armstrong & Co. Catalogue of Educational Publications.
105. Sève, Edmourd. Le Chili tel qu'il est.
197. Shaler, N. S. General Account of the Commonwealth of Kentucky.
88. Shantz, J. Y. Relation d'un voyage a Manitoba.
54. Smart, James H. Indiana Schools and the men who have worked in them.
205. " " Public Instruction in Indiana. Twenty-third Annual Report.
157. Smith College. Report.
199. " Walter. Circular of the Massachusetts Normal Art School.
119. Soldiers Orphans. Annual Report of Pennsylvania Superintendent.
77. South Australia. Its history, resources, etc. Wm. Harcens.
90. Spence, Thomas. Manitoba and the North-west of the Dominion.
162. Sullivan, Sir Ed. Bart. Protection to Native Industry.
86. Sweden. Catalogue of Exhibit by Motala Iron and Steel Works.
88. " Exhibition of Geological Survey.
145. " Hammers Museum. Synopsis.
60. " Swedish Catalogue. Part 1st.
185. Switzerland. Bericht der Eidgenössischen Polytechnischen Schule in Zürich.
41. " Catalogue of Swiss Section.
177. " Report of Artisan's School in St. Gall.
183. " Report of Swiss Unions of Young Merchants, 1876.
142. Tennessee. Its Agricultural and Mineral Wealth.
167. Thompson, Chas. O. Report of the Worcester Free Institution.
182. Trow, Jas. A Trip to Manitoba.
146. Tunis. Règlement des études à la grande Mosquée de Tunis.
234. University of Michigan. Calendar, 1876–6.
165. University of Pennsylvania. Catalogue and Announcement. 1874–5.
166. " " " " 1875–6.
174. " " " " 1876–77.
114. " " Publications by the Medical Department.
61. U. S. Naval Observatory. Reports of Foreign Societies on awarding medals to American Arctic Explorers.
103. Vansant, I. L. The Royal Road to Wealth.
43. Victoria, Australia. Catalogue of Exhibit.
187. Villars, Gauthier. Catalogue des Livres de Fonds, 1876.
116. Warren Street Chapel. Thirty-Eighth Annual Report.
173 Wharton, Joseph. National Self Protection.
235. Wickersham, J. P. The Pennsylvania School Journal. Aug. 1876.
93. Willmett, T. Northern Queensland Directory.
95. Wisconsin. Catalogue and Sketches.
44. " State Report and Catalogue.
202. Wootten, J. E. The Philadelphia and Reading Rail Road.
22. W. Virginia. Catalogue of State Exhibit.

CLASS 2. CIVIL ENGINEERING.

67. American Bridge Co. Album of Designs.
43. Boston. Seventh Annual Report of the Railroad Commissioners.
22. Brazil. Map of the General Railroads and Telegraph lines in Brazil.
23. " " " Provincial Railroads.
24. " " " " " Province of St. Pauls.
26. " Topographical Map of the Province of St. Pauls.
25. " General Map of the Empire.
42. " Railroads of the Province of St. Pauls.
64. Clarke Reeves & Co. Centennial Catalogue and Publications.
2. " " " Photograph of Chain Bridge over Potomac River.
3. " " " " Biddeford Bridge over Saco River. Eastern Railroad.
4. " " " " Trumansburgh Viaduct, Geneva & Ithica Railroad.
38. Davis, Rear Admiral Chas. H. Interoceanic Communication between Atlantic and Pacific Oceans.
39. " " " " Same as preceding, with Maps.
44. Deutschlands. Der Buchhandel und die graphischen künste, auf der wellausselung zu Philadelphia, 1876.
47. France. Description of the Models, Charts and Drawings relating to the works of the "Ponts et Chaussées" and the Mines.
48. " Same as preceding. (In French.)
49. " Historical and Statistical Studies upon the means of communication in France.
45. Heller & Brightly, Philadelphia. Remarks on Engineer's Surveying Instruments.
62. Holyoke, Mass. City Water Power and Industries.
34. Keystone Bridge Co. Description of Raritan Swing Bridge.
35. " " " Illustrated Circular of Long Span Bridges.
36. " " " Illustrated Albums.
5. Keystone Bridge Co. Photographs. Three views (side, end, and top) of Collowhill Street Bridge over Schuylkill River at Philadelphia.
6. " " " Collowhill Street Bridge (side view).
7. " " " Terre Haute & Indianapolis Railroad Bridge over Wabash River at Terre Haute, Ind.
8. " " " Ohio River Bridge, Parkersburg, West Virginia, Baltimore and Ohio R.R. (end view).
9. " " " " " (side view).
10. " " " Illinois and St. Louis Bridge (finished structure).
11. " " " " " end span (in process of erection).
12. " " Illinois & St. Louis Bridge; all spans (in process of erection).
13. " " " " " Two spans " "
14. " " " " " All spans " "
15. " " Blanks for specifications of Bridge.

16. Keystone Bridge Co. Photographs Ohio River Bridge, Cincinnati Southern Railway. Five sheets of designs.
17. " " " J. L. Piper's Improved Centre for Wrought-iron Turntables.
18. " " " J. L. Piper's Patent Hollow Wrought-iron Columns.
19. " " " Wrought-iron Highway Bridge.
20. " " " " Railway Bridge.
21. " " " Details for wrought-iron Bridge over Mississippi River at Rock Island.
68. Kneffel & Esser. Catalogue of Draughting Instruments.
46. Lyman ——. Description of Lyman's Trigonometer and Universal Draughting Instrument.
66. Mexico. History of the Railway wealth of Mexico.
61. Netherlands. Eckstein, Charles. New method for reproducing Maps and Drawings.
50. Netherlands. Photo-Lithographs. Bridge over the Hollandsch Diep.
51. " " Reclamation of Haarlemmermeer.
52. " " Pneumatic Foundation of the Railway Bridge before the Madse at Rotterdam.
53. " " Bridge at Bommel.
54. " " New Channel from Rotterdam to the North Sea.
55. " " Steel Swing Bridge at Dordrecht.
56. " " A. Lifting-bridge over the Linge. B. Swing-bridge over the North Holland Canal.
57. " " Canal from Amsterdam to the North Sea.
58. " " Bridge at Hurlenburg.
59. " " A. Dam across the Sloe. B. " " Schelde.
60. " Sketch of the Public Works.
33. " View of the Harbor of Flushing.
41. Norman, V. Report on the Design and Construction of a Military Bridge Equipage, 1876.
37. Phoenixville Bridge Co. Clarke, Reeves & Co. Supplement to Album of Designs.
37a. " " Illustrated Album of Designs.
65. Roebling, John A. & Sons. Catalogue and Price-list of Wire Rope.
63. Switzerland. Atlas uber die entwicklung von Industrie und Handel, der Schweiz.
29. " R. Lurzinger, Topographer at Berne. One Map Section Grono.
30. " Wurster, Randegger, & Co. School Atlas.
31. " " " " "
32. " North-East Railroad Co. Album of Road and Stations——Designs.
1. U. S. Navy. Catalogue of Centennial Exhibit.
40. U. S. Naval Observatory. Instruments and Publications, 1845—1876.

CLASS 3. MECHANICAL ENGINEERING.

19. Arbey, Fd. Illustrated Catalogue of Wood-working Machinery.
49. Aveling & Porter. Road Locomotives, &c. Illustrated pamphlet.
17. Avery, John G., Worcester, Mass. Catalogue of Thread and Twine Machinery.
45. Bough & Sons. Bough's Sectional Mills. Illustrated pamphlet.

81. Botelho de Mayalhaes, Benjamin Constant. Theora das Quantidades Negativas.
41. Buckeye Engine Co. Illustrated circular.
11. Butterworth, H. W. & Sons. Photographs of Drying Machines and Improved Stuffing-boxes.
28. Douglass Manufacturing Co. Descriptive Price-list of Mechanics' Tools.
8 & 36. Eaton, Cole & Burnham. Illustrated catalogue of Steam and Gas-fitters' Supplies.
21. Empire Threshing Machine Co. Descriptive circular.
24. Ferris & Miles. Steam Hammers and Machine Tools.
12. Fitchburg Machine Co. Twelve photographs of Improved Machinery.
47. Ganguillet & Kutter. Hydraulics. Motion of Water in Canals and Rivers.
35. Greenlee Brothers & Co. Descriptive catalogue of Wood-working Machinery.
30. Hampson, Whitehill & Co. "Engines and Boilers."
32. Harrison, Edward. Standard Flouring Mills. Illustrated pamphlet.
37. Hoops & Townsend. Bolts and Screws. Descriptive catalogue and price-list.
9. " " Photographs of Bolts, Screws, &c.
39. Hotchkiss, A. S. The Tower Clocks made by Seth Thomas & Co.
35. Howe & Co. Howe's Improved Scales. Illustrated pamphlet.
6. Kirkaldy. Experimental inquiry into the properties of Fayersta Steel.
51. Krupp, Fried., Essen, Germany. Cast-steel and Iron. Descriptive publications.
38. Leffell, James. Improved double Turbine Water-wheel.
43. Lyall, J. & W. Lyall's Positive Motioned Loom.
42. Mast, P. P. & Co. Agricultural Machinery.
18. Mirrlees, Tait & Watson. Photograph of Sugar Mill.
18. Mitchell, J. E. Catalogue of Grindstones and Fixtures.
22. National Fire Alarm Co. Description of Apparatus.
15. Northampton Emery Wheel Co., Leeds, Mass. Catalogue and price-list.
44. Noye, John T. & Sons. Portable Flouring and Grist Mills.
3. Nystrom. New treatise on Steam Engineering.
2. " Elements of Mechanics.
27. Otis Brothers, Yonkers, N. Y. Descriptive pamphlets of Otis Elevators and Hoisting Machinery.
16. Pence, Cox & Co. Steam and Gas Fitters Tools. Catalogue and price-list.
25. Perkins, A. M. & Son. London Heating Apparatus. Descriptive pamphlet.
26. Philadelphia Burring Machine Works. Descriptive pamphlet.
28. Porter, Bell & Co. Light Locomotives. Illustrated description.
24. Pratt & Whitney Co. Descriptive catalogue.
48. Rodney, Hunt & Co. Hunt's Double-acting Turbine Water-wheel. Descriptive circular.
1. Russia. Description of the Scientific Appliances in the Imperial Technical School at Moscow.
50. Shapley & Wells. "The Shapley Engine."
20. Siemen & Co. Description of Regenerative Gas Furnace.
29. Smith, James & Co. Manufacturers Supplies. Illustrated catalogue.
40. South Bend Iron Works. Description of the Works at South Bend, Indiana.
5. Sweden. The state of the Iron Manufacture.
4. Switzerland. Illustrated description of the large Water-works at Bellegrade.
46. Utica Steam Gauge Co. Descriptive circular.
14. Wetherell, Robert & Co. Photograph of Engine Regulator.
7. Yale Lock Manufacturing Co. Illustrated catalogue.

CLASS 4. MINING ENGINEERING.

6. Actien-Gesellschaft fur Anolin-Fabrikation; coal tar products and analine colors.
4. Akerman, Rich. State of the Iron Manufacture in Sweden at the beginning of 1876.
1. Analysen von Durchschnittsproben des Zur Hemrichshütte bei Au an der sieg producirten Prima spiegeleisens Morke.
5. Boyer, Fredr. & Co. Department of Analine Colors.
2. Krupp, Fried. The Cast-steel and Iron Works at Essen, Germany.
7. Moore, J. G. & Co. "Creosoting by Bethell Process."
8. New South Wales. "Mines and Mineral Statistics."
10. Pennsylvania Steel Co. Catalogue and Album.
9. Sawyer, Fredr. E. "The Coal Trade."
3. Whitewell, —. Illustrated Paper on Whitewell's Patent Fire Brick Stoves.

CLASS 5. ARCHITECTURE.

1. Mott, J. L. & Co. Catalogue of Ornamental Designs.
4. Spain. Conservatory of Arts at Madrid. Perspective Drawings by Evening Classes.
5. " " " " Geometric Drawings.
6. " " " " Human Figure and Ornamental Drawing.
7. " " " " Young Ladies Class.
8. " " " " Water Color Drawing.
3. Switzerland. Kantonsrathhaus herausgegeben durch die Bandirection des Kantons. Bern, 1876.
2. Switzerland. Neue Entbindnuysanstalt herausgegeben durch die Banderection des Kantons. Bern, 1876.

CLASS 5½. PHYSICS.

4. Coston, J. Description of Coston's Telegraphic Night Signals.
3. Juvet, L. P. Glen Falls, N. Y. Photograph of New Time Globe.
2. Western Electric Manufacturing Co., Chicago. Catalogue and price-list.
1. " " " Samples of Insulated Telegraphic Wire.

CLASS 6. ARTICLES CONSTRUCTED FROM WOOD AND IRON FOR PURPOSES OF INSTRUCTION.

From the Imperial Technical School at St. Petersburg, Russia. Department of Industrial Art.

Course No. I. Six pieces of cast iron finished with the file by students, showing the course of instruction in the art of filing.

Course No. II. Nineteen pieces of wrought iron forgings showing the course of instruction in the art of forging.

Course No. III. Seventeen pieces of wrought iron showing the course of instruction in the art of turning.

From the Artisans' School at Rotterdam, Holland.

Complete drawings of the workshops for boys from twelve to fifteen years of age.

The crosshead, governor, connecting rod and valve rod for an upright engine.

Two locks, showing instruction given in filing and fitting. Fourteen forgings showing instruction given in the smith's shop.

Two specimens of copper work, including brazing.

One pulley block and one post showing work done in the turning shop.

Fifteen specimens of carpenters' work, including stair building. Three specimens of carving and inlaid work.

Six specimens of painting upon cloth.

DEPARTMENT II. — AGRICULTURE.

CLASS 7. TIMBER AND USEFUL WOODS.

AUSTRALIA.

From the Colony of Queensland.

1. Araucaria Bidwillii, Hook. Bunya Bunya. Diameter, 30 to 48 in.; height, 100 to 220 ft.

2. Araucaria Cunninghamii, Ait. Moreton Bay Pine. Diameter, 36 to 66 in.; height, 150 to 200 ft.

3. Dammara robusta, Moore. Kawrie or Dundathu Pine. Diameter, 36 to 72 in.; height, 80 to 130 ft.

4. Callitris columellaris, F. Muell. Cypress Pine. Diameter, 20 to 30 in.; height, 40 to 60 ft.

5. Callitris verrucosa, R. Br. The Desert Cypress Pine. Diameter, 12 to 24 in.; height, 50 to 70 ft.

6. Callitris Endlicheri, Parl. The Mountain Cypress Pine. Diameter, 9 to 18 in.; height, 40 to 50 ft.

7. Podocarpus elatus, R. Br. She Pine. Diameter, 20 to 36 in.; height, 50 to 80 ft.

8. Casuarina tenuissima, Sieb. River Oak. Diameter, 18 to 22 in.; height, 40 to 70 ft.

9. Casuarina leptoclada, Miq. The Erect She Oak. Diameter, 9 to 15 in.; height, 20 to 30 ft.

10. Casuarina equisetifolia, Forst. Swamp Oak. Diameter, 12 to 20 in.; height, 50 to 70 ft.

11. Casuarina torulosa, Ait. Forest Oak, Beef wood. Diameter, 9 to 15 in.; height, 30 to 35 ft.

12. Casuarina Cunninghamiana, Miq. Fire Oak. Diameter, 6 to 10 in.; height, 20 to 30 ft.

13. Cedrela Toona, Roxb. Red Cedar. Diameter, 24 to 76 in.; height, 100 to 150 ft.

14. Flindersia Australis, R. Br. Flindosa. Diameter, 36 to 48 in.; height, 80 to 100 ft.

15. Flindersia Oxleyana, F. Muell. Light-Yellow Wood. Diameter, 24 to 42 in.; height, 80 to 100 ft.

16. Flindersia Bennettiana, F. Muell. Bogum Bogum. Diameter, 18 to 26 in.; height, 70 to 90 ft.

17. Flindersia maculosa, F. Muell. Spotted Tree of the Colonists. Diameter, 12 to 18 in.; height, 30 to 40 ft.

18. Owenia venosa, F. Muell. Sour Plum. Diameter, 12 to 24 in.; height, 40 to 65 ft.

19. Owenia cerasifera, F. Muell. Sweet Plum. Diameter, 9 to 18 in.; height, 25 to 35 ft.

20. Amoora nitidula, Benth. Diameter, 18 to 30 in.; height, 70 to 90 ft.

21. Synoum glandulosum, A. Juss. Diameter, 15 to 24 in.; height, 35 to 60 ft.

22. Dysoxylon Muelleri, Benth. Pencil Cedar. Diameter, 20 to 35 in.; height, 70 to 90 ft.

23. Melia composita, Willd. Diameter, 15 to 20 in.; height, 50 to 60 ft.

24. Ailanthus imberbiflora, F. Muell. Diameter, 20 to 28 in.; height, 50 to 70 ft.

25. Bosistoa sapindiformis, F. Muell. Diameter, 6 to 12 in.; height, 15 to 20 ft.

26. Citrus australis, Planch. Native Orange. Diameter, 6 to 14 in.

27. Citrus australasica, F. Muell. Native Lime. Diameter, 6 to 10 in.: height, 15 to 20 ft.

28. Atalantia glauca, Hook. The Native Cumquat. Diameter, 2 to 6 in.; height, 8 to 15 ft.

29. Acronychia Baueri, Schott. Diameter, 6 to 12 in.; height, 16 to 24 ft.

30. Acronychia lævis, Forst. Diameter, 15 to 20 in.; height, 30 to 50 ft.

31. Zanthoxylon brachyacanthum, F. Muell. Satin Wood. Diameter, 6 to 9 in.; height, 20 to 30 ft.

32. Geijera parviflora, Lindl. Diameter, 6 to 12 in.: height, 20 to 30 ft.

33. Geijera Muelleri, Benth. Balsam Capivi Tree. Diameter, 12 to 18 in.; height, 40 to 60 ft.

34. Evodia micrococca, F. Muell. Diameter, 6 to 10 in.; height, 20 to 30 ft.

35. Celastrus dispermus, F. Muell. Diameter, 3 to 5 in.; height, 12 to 16 ft.

36. Denhamia pittosporoides, F. Muell. Diameter, 6 to 8 in.; height, 20 to 30 ft.

37. Denhamia obscura, Meisn. Diameter, 3 to 5 in.; height, 12 to 20 ft.

38. Alphitonia excelsa, Reissek. Mountain or Red Ash. Diameter, 18 to 24 in.; height, 45 to 60 ft.

39. Pittosporum rhombifolium, A. Cunn. Diameter, 6 to 12 in.; height, 40 to 55 ft.

40. Pittosporum bicolor, Hook. Diameter, 6 to 21 in.; height, 20 to 40 ft.

41. Pittosporum phillyræoides, D. C. Diameter, 4 to 6 in.; height, 20 to 35 ft.

42. Tarrietia argyrodendron, Benth. Silver Tree. Diameter, 24 to 34 in.; height, 70 to 90 ft.

43. Tarrietia actinodendron, F. Muell. Diameter, 18 to 30 in.; height, 60 to 70 ft.

44. Commersonia echinata, Forst. Diameter, 6 to 12 in.; height, 20 to 30 ft.

45. Cupania xylocarpa, A. Cunn. Diameter, 12 to 24 in.; height, 40 to 60 ft.

46. Cupania serrata, F. Muell. Diameter, 8 to 14 in.; height, 20 to 30 ft.

47. Diploglottis Cunninghamii, Hook. Native Tamarind. Diameter, 12 to 20 in.; height, 40 to 55 ft.

48. Cupania semiglauca, F. Muell. Diameter, 10 to 20 in.; height, 30 to 60 ft.

49. Ratonia pyriformis. Benth. Diameter, 10 to 18 in.; height, 30 to 45 ft.

50. Nephelium tomentosum, F. Muell. Diameter, 10 to 15 in.; height, 30 to 40 ft.

51. Heterodendron oleæfolium, Desf. Diameter, 4 to 10 in.; height, 20 to 30 ft.

52. Heterodendron diversifolium, F. Muell. Diameter, 4 to 6 in.; height, 10 to 15 ft.

53. Harpullia pendula, Planch. Tulip Wood. Diameter, 14 to 24 in.; height, 50 to 60 ft.

54. Dodonæa triquetra, Andr. Hop Bush. Diameter, 3 to 4 in.; height, 10 to 12 ft.

55. Rhus rhodanthema, F. Muell. Dark Yellow Wood, K. Diameter, 18 to 24 in.; height, 50 to 70 ft.

56. Sarcocephalus cordatus, Miq. Leichhardt's Tree. Diameter, 24 to 30 in.; height, 40 to 60 ft.

57. Ixora Pavetta Roxb. Diameter, 2 to 4 in.; height, 8 to 10 ft.

58. Hodgkinsonia ovatiflora, F. Muell. Diameter, 6 to 10 in.; height, 12 to 20 ft.

59. Canthium lucidum, Hook, and Arm. Diameter, 6 to 12 in.; height, 20 to 30 ft.

60. Canthium oleifolium, Hook. Diameter, 4 to 10 in.; height, 25 to 30 ft.

61. Canthium latifolium, F. Muell. Diameter, 8 to 12 in.; height, 25 to 30 ft.

62. Canthium vacciniifolium, F. Muell. Diameter, 2 to 4 in.; height, 6 to 10 ft.

63. Cœlospermum paniculatum, F. Muell. Diameter, 3 to 5 in.; height, 100 to 150 ft.

64. Callistemon lanceolatus, D. C. Bottle-brush Tree. Diameter, 12 to 18 in.; height, 30 to 40 ft.

65. Callistemon salignus, D. C. Broad-leaved Tea Tree. Diameter, 18 to 24 in.; height, 40 to 60 ft.

66. Melaleuca linariifolia, Sm. Diameter, 20 to 24 in.; height, 30 to 40 ft.

67. Melaleuca nodosa, Sm. Tea Tree. Diameter, 10 to 20 in.; height, 30 to 40 ft.

68. Angophora subvelutina, F. Muell. Apple Tree. Diameter, 20 to 26 in.; height, 40 to 60 ft.

69. Eucalyptus pilularis, Sm. Black-butt. Diameter, 24 to 40 in.; height, 60 to 80 ft.

70. Eucalyptus Microcorys, F. Muell. Diameter, 18 to 30 in.; height, 60 to 80 ft.

71. Eucalyptus hemiphloia, F. Muell. Yellow Box. Diameter, 20 to 30 in.; height, 40 to 60 ft.

72. Eucalyptus siderophloia, Benth. Ironbark. Diameter, 20 to 30 in.; height, 60 to 80 ft.

73. Eucalyptus melcanophloia, F. Muell. Silver-leaved Ironbark. Diameter, 18 to 20 in.; height, 30 to 60 ft.

74. Eucalyptus maculata, Hook. Spotted Gum. Diameter, 20 to 30 in.; height, 60 to 80 ft.

75. Eucalyptus saligna, Sm. Grey Gum. Diameter, 24 to 34 in.; height, 60 to 80 ft.

76. Eucalyptus Resinifera, Sm. Red Mahogany. Diameter, 20 to 30 in.; height, 60 to 70 ft.

77. Eucalyptus corymbosa, Sm. Bloodwood. Diameter, 24 to 30 in.; height, 50 to 60 ft.

78. Eucalyptus globulus, Sm. Blue Gum. Diameter, 30 to 48 in.; height, 70 to 90 ft.

79. Eucalyptus tereticornis, Sm. Red Gum. Diameter, 18 to 30 in.; height, 60 to 80 ft.

80. Eucalyptus Stuartiana, F. Muell. Turpentine Tree. Diameter 24 to 36 in.; height, 60 to 80 ft.

81. Eucalyptus fibrosa, F. Muell. Stringy Bark. Diameter, 18 to 24 in.; height, 40 to 60 ft.

82. Eucalyptus tesselaris, F. Muell. Moreton Bay Ash. Diameter, 14 to 24 in.; height, 30 to 60 ft.

83. Myrtus acmenioides, F. Muell. Diameter, 12 to 18 in.; height, 30 to 40 ft.

84. Eugenia Smithii, Poir. Lilly Pillies. Diameter, 12 to 18 in.; height, 30 to 40 ft.

85. Myrtus Hillii, Benth. Scrub Ironwood. Diameter, 6 to 12 in.; height, 20 to 40 ft.

86. Rhodamnia trinervia, Blum. Diameter, 10 to 18 in.; height, 20 to 30 ft.

87. Rhodomyrtus psidioides, Benth. Diameter, 12 to 20 in.; height, 30 to 40 ft.

88. Rhodamnia argentea, Benth. Diameter, 15 to 22 in.; height, 40 to 60 ft.

89. Tristania conferta, R. Br. Box. Diameter, 36 to 50 in.; height, 80 to 100 ft.

90. Grevillea robusta, Cunn. Silky Oak. Diameter, 30 to 40 in.; height, 80 to 100 ft.

91. Macadamia ternifolia, F. Muell, Queensland Nut. Diameter, 30 to 40 in.; height, 30 to 50 ft.

92. Orites excelsa, R. Br. Diameter, 6 to 14 in.; height, 30 to 60 ft.

93. Banksia integrifolia, Linn. Beef Wood. Diameter, 8 to 12 in.; height, 20 to 30 ft.

94. Persoonia lucida, R. Br.; var. latifolia, A. Cunn. Diameter, 3 to 7 in.; height, 10 to 20 ft.

95. Grevillea Hilliana, F. Muell. Diameter, 10 to 18 in.; height, 40 to 60 ft.

96. Exocarpus latifolia, R. Br. Broad-leaved Cherry Tree. Diameter, 6 to 9 in.; height, 12 to 25 ft.

97. Exocarpus cupressiformis, R. Br. Cherry Tree. Diameter, 4 to 8 in.; height, 10 to 16 ft.

98. Santalum lanceolatum, R. Br. Sandal Wood. Diameter, 3 to 6 in.; height, 15 to 25 ft.

99. Eremophila Mitchelli, Benth. Bastard Sandal Wood. Diameter, 6 to 12 in.; height, 20 to 30 ft.

100. Myoporum acuminatum, R. Br.; var. parviflorum, Benth. Diameter, 4 to 6 in.; height, 12 to 15 ft.

101. Avicennia officinalis, Linn. Mangrove. Diameter, 19 to 20 in.; height, 20 to 30 ft.

102. Gmelina Leichhardtii, F. Muell. Beech. Diameter, 24 to 36 in.; height, 80 to 100 ft.

103. Vitex lignum-vitæ, A. Cunn. Shrub Lignum Vitæ. Diameter, 20 to 24 in.; height, 50 to 70 ft.

104. Elæocarpus obovatus, G. Don. Diameter, 12 to 20 in.; height, 30 to 40 ft.

105. Acacia falcata, Willd. Diameter, 6 to 12 in.; height, 20 to 30 ft.

106. Acacia glaucescens, Willd. Diameter, 12 to 18 in.; height, 30 to 35 ft.

107. Same as 8 in a younger stage.

108. Acacia fasciculifera, F. Muell. Diameter, 10 to 16 in.; height, 30 to 40 ft.

109. Acacia salicina, Lindl. Diameter, 6 to 12 in.; height, 30 to 40 ft.

110. Acacia harpophylla, F. Muell. Diameter, 12 to 20 in.; height, 40 to 70 ft.

111. Same as 110 in a younger stage.

112. Acacia excelsa, Benth. Brigalow. Diameter, 20 to 30 in.; height, 50 to 80 ft.

113. Acacia neriifolia, A. Cunn. Diameter, 6 to 12 in.; height, 20 to 30 ft.

114. Acacia doratoxylon, A. Cunn. Diameter, 6 to 12 in.; height, 25 to 35 ft.

115. Acacia pendula, A. Cunn. Weeping Myall. Diameter, 6 to 12 in.; height 20 to 35 ft.

116. Acacia stenophylla, A. Cunn. Ironwood. Diameter, 15 to 24 in.; height, 40 to 60 ft.

117. Acacia leptostachya, Benth. Diameter, 4 to 10 in.; height, 20 to 25 ft.

118. Acacia uncifera, Benth. Diameter, 3 to 5 in.; height, 6 to 10 ft.

119. Acacia decurrens, Willd; Green Wattle. Diameter, 3 to 8 in.; height, 30 to 40 ft.

120. Acacia amblygona, A. Cunn. Diameter, 6 to 10 in.; height, 20 to 25 ft.

121. Acacia decurrens, Willd. var. mollis, Lindl. Silver Wattle. Diameter, 6 to 10 in.; height, 30 to 40 ft.

122. Albizzia thozetiana, F. Muell. Diameter, 12 to 30 in.; height, 40 to 60 ft.
123. Acacia linifolia, Willd. Diameter, 3 to 4 in.; height, 10 to 15 ft.
124. Acacia penninervis, Sieb. Diameter, 2 to 4 in.; height, 6 to 12 ft.
125. Pithecolobium pruinosum, Benth. Diameter, 5 to 12 in.; height, 40 to 50 ft.
126. Hovea acutifolia, A. Cunn. Diameter, 2 to 4 in.; height, 6 to 10 ft.
127. Barklya syringifolia, F. Muell. Diameter, 12 to 18 in.; height, 40 to 60 ft.
128. Cassia Brewsteri, F. Muell. Diameter, 3 to 6 in.; height, 30 to 50 ft.
129. Jacksonia scoparia, R. Br. Dogwood. Diameter, 3 to 8 in.; height, 10 to 15 ft.
130. Marlea vitiensis, Benth. Musk Tree. Diameter, 6 to 12 in.; height, 20 to 30 ft.
131. Olea paniculata, R. Br. Native Olive. Diameter, 18 to 24 in.; height, 50 to 70 ft.
132. Notelæa ovata, R. Br. Dunga Vunga. Diameter, 6 to 12 in.; height, 20 to 30 ft.
133. Notelæa microcarpa, R. Br. Diameter, 9 to 12 in.; height, 30 to 45 ft.
134. Endiandra pubens, Meissn. Diameter, 18 to 24 in.; height, 40 to 70 ft.
135. Tetranthera ferruginea, R. Br. Diameter, 14 to 20 in.; height, 30 to 40 ft.
136. Litsæa dealbata, Nees. Diameter, 18 to 24 in.; height, 40 to 60 ft.
137. Cryptocarya patentinervis, F. Muell. Diameter, 12 to 20 in.; height, 30 to 40 ft.
138. Cargillia australis, R. Br. Diameter, 6 to 12 in.; height, 30 to 40 ft.
139. Mallotus philippinensis, F. Muell. Diameter, 6 to 14 in.; height, 30 to 45 ft.
140. Mallotus nesophilus, F. Muell. Diameter, 12 to 18 in.; height, 35 to 45 ft.
141. Croton insularis, Baill. Cascarilla. Diameter, 8 to 12 in.; height, 30 to 40 ft.
142. Croton Verreauxii, Baill. Diameter, 3 to 5 in.; height, 15 to 20 ft.
143. Petalostigma quadriloculare, F. Muell. Crab Tree. Diameter, 12 to 18 in.; height, 40 to 50 ft.
144. Excæcaria Agallocha, Linn. River Poisonous Tree. Diameter, 6 to 18 in.; height, 20 to 30 ft.
145. Bridelia exaltata, F. Muell. Diameter, 12 to 18 in.; height, 30 to 45 ft.
146. Bradleia australis, R. Br. Diameter, 12 to 18 in.; height, 13 to 50 ft.
147. Daphnandra Micrantha, Benth. Diameter, 18 to 30 in.; height, 60 to 80 ft.
148. Hormogyne cotinifolia, A. DC. Diameter, 6 to 9 in.; height, 20 to 35 ft.
149. Chrysophyllum pruniferum, F. Muell. Diameter, 12 to 20 in.; height, 30 to 70 ft.
150. Celtis phillippinensis, Blanco. Diameter, 4 to 12 in.; height, 20 to 40 ft.
151. Morus calcar-galli, Cunn. Cockspur Thorn.
152. Ceratopetalum apetalum, Don. Coachwood. Diameter, 24 to 36 in.; height, 70 to 90 ft.

CLASS 8. WOOL, WASHED AND UNWASHED.

Nos. 1 to 89 inclusive are specimens of cloths manufactured in the Netherlands and Brazil, and will be found under the head of Manufactures, Department IV, Class 30.

TASMANIA.

90. Work done by Parkhurst's Patent Burring Picker.
91. Merino, weight 11 lbs. before being skirted.
92. Unwashed fleece.
93. " " No. 1, Extra.
94. Medium qual., washed.
95. Unwashed fleece from the Ram "Duke."
96. Commercial fleece, washed.
97. Unwashed fibre, nine inches long.
98. Exhibition by F. Shaw.
99. Fleece, washed.

100. Merino from unwashed fleece.
101. Washed on the sheep.
102. Extra quality washed.
103. Unwashed.
104. Washed by hand. Extra long and fine.
105. Washed. Extra quality.
106. Merino fleece, 1st quality, unwashed.
107. Commercial, washed.
108. Medium quality — washed and unwashed.
109. Merino, extra quality, unwashed.
110. Fleece, unwashed.
111. Merino, as shorn from sheep.
112. Lamb's, extra quality.
113. Fine fleece, washed.
114. Leicester.
115. Medium quality.
116. Fleece, Merino, medium quality, unwashed.
117. Commercial.
118. Merino, medium quality, unwashed.
119. 1st quality, washed in the fleece.
120. Extra quality lamb's wool, washed.
121. Good quality, long fibre.
122. Medium quality, washed.
123. Merino, 1st quality, washed.
124. Merino, unwashed.
125. Medium quality.
126. Extra quality lamb's wool.
127. Fleece, unwashed.
128. Coarse wool, 13 inches long.

AUSTRALIA.

129. Merino, 1st quality, unwashed.

New South Wales.

130. Merino, extra No. 1.
131. Merino, unwashed.
132. No. 1, unwashed.
133. Merino fleece, washed.
134. Merino, 1st quality, unwashed.
135. Merino, washed.
136. Merino, unwashed, extra No. 1.
137. Merino fleece, unwashed.
138. 1st quality.
139. Merino, 2d quality.
140. 1st quality.
141. Merino, unwashed.
142. 1st quallty, washed.
143. Merino, washed.
144. Fair Merino.
145. Cotswold.
146. Washed in the fleece.
147. 3d quality, unwashed.
147. Merino fleece, extra quality.
149. Merino, 2d quality.
150. Merino fleece, No. 1.
151. Prime quality, unwashed.
152. Medium, washed
153. Fine Merino, washed.
154. No. 3, unwashed.
155. Merino, 2d quality.
156. Merino, No. 3, fleece.
157. Merino, good quality, unwashed.
158. Lamb's, washed.
159. Medium, unwashed.
160. Merino, extra fine and long.
161. No. 1, washed.
162. Merino, unwashed.
163. Extra quality, washed.
164. Merino, washed.
165. Fair quality.
166. Medium quality.
167. Merino, No. 3, washed.
168. No. 1, unwashed.
169. Merino, unwashed.
170. Medium fleece, washed.
171. No. 1, unwashed.
172. Extra fine fleece, washed.
173. Fleece, washed.
174. " "
175. Merino, No. 2, unwashed.
176. Merino fleece, washed.
177. " " "
178. Merino fleece, extra quality, unwashed.
179. Medium quality, unwashed.
180. Merino, No. 2, unwashed.
181. Medium quality, unwashed.
182. Fleece No. 1, washed.
183. Medium, washed by hand.
184. Extra Merino, washed by hand.
185. 1st quality, washed by hand.
186. Merino, No. 1, washed.
187. No. 1, Merino, washed.
188. 1st quality Merino, washed.
189. Merino, No. 1, washed.
190. Medium, unwashed.
190*a*. " washed.
190*b*. No. 1, washed.

Victoria.

191. Greasy fleece wool.
192. Hot water worked fleece.
193. Washed on the animal; age when shorn 6 months.
194. From Melbourne.
195. Ewes, washed.
196. Greasy fleece.
197. Merino ewe's fleece.
198. Greasy Lincoln.
199. Merino ewe's, fed on natural pasturage only.
200. Greasy Merino.
201. Wethers, greasy Merino; 12 months' growth.
202. Washed ewe's fleece.
203. Greasy Merino ewe's fleece.
204. Greasy crossbred.
205. "
206. " Merino.
207. Hot water washed.
208. Greasy Leicester.
209. Merino ewe's.
210. Greasy crossbred.
211. " Merino.
212. Washed Merino.
213. Fleece, hot water washed.
214. Merino, wether.
215. Washed fleece.
216. Young ewes, hot water washed.
217. Washed fleece.
218. From Geelong.
219. Greasy Merino.
220. Washed Merino.
221. Greasy Merino.
222. " "
223. Washed Merino ewe's fleece.
224. Greasy fleece.
225. Washed Merino.
226. Greasy fleece.
227. " Merino lamb's.
228. " crossbred.
229. Wool.
230. Greasy Lincoln.
231. " "
232. From Thos. F. Cumming.
233. " "
234. " "
235. " "
236. Washed Merino,
237. Merino lamb's, hot water washed.
238. Greasy Merino.
239. Cheviot ewes.
240. Greasy Merino ewe's.
241. Washed ewe's.
242. " crossbred.
243. Merino.
244. Scoured fleece.
245. Washed Merino lamb's.
246. " "
247. Greasy.
248. " crossbred.
249. Cheviot lamb's.
250. " "
251. " "
251*a*. " "
251*b*. Merino ewe, 12 month's growth.
251*c*. Ewe lamb, 12 month's growth.

Queensland.

252. Merino.
253. "
254. "
255. "
256. "
257. "
258. "
259. " 2d quality unwashed.
260. " " " washed by hand.
261. " " " unwashed.

TASMANIA.

262. Merino, 1st quality.
263. Known as No. 74.
264. Merino, unwashed.
265. Fleece from Merino ram.
266. Merino, unwashed.
267. " "
268. " "
269. from the ram "Melhimus."
270. from ewe.
271.

AFRICA.

Cape of Good Hope.

272. Wool known as Tides.
273. Merino unwashed.
274. " fleece.
275. "
276. Known as No. 95.
277. " fleece.
278. " unwashed.
279. " in the natural grease.
280. Wool.

281. Angora hair.
282.
283. Wool, scoured.
284. " 95.
285. " Merino.

RUSSIA.

286. Merino, washed.
287. " "
288. " "
289. " "
290. " unwashed.
291.
292.
293. Merino, unwashed.
294. " washed.
295. " "
296. " unwashed.
297. Goat's hair.

TURKEY.

298. Angora hair.
299. Goat's hair.
300. Camel's hair from Bagdad.
301. " " " Aleppo.
302. " " " Dardanelles.
303. Goat's " " Sivas.

CANADA.

304. Hamilton wool, 27 cts. per lb.
305. Cotswold fleece.
306. Wool.
307. "
308. "
308*a*. "
309. "
310. " John Harvey & Co.
310*a*. " " " 30 cts. per lb.

BRAZIL.

311. Wool.
312. "

CLASS 9. HAIR, BRISTLES, ETC.

BRAZIL.

313. Hair.
314. Hair.

TURKEY.

315. Camel's hair.
316. " " Esine.
317. " " Bagdad.
318. Bagdad, coarse wool, washed.
319. Konieh, Hair or coarse wool.
320. Erzeroum, Camel's hair.
321. Castamanni, Hair.
322. "Duvet de chien."
323. Adana, Camel's hair, very long.
324. Smyrna, Wool.
325. " "
326. Konieh, "
327. Wool.
328. Coarse wool.
329. Castamanni wool.
330. Bagdad, "
331. Prérézé, " unwashed.
332. Tripoli, woolen yarn.
333. Broussl, thread, black silk.

CLASS 10. SILK IN THE COCOON AND REELED.

TURKEY.

334. Samos, Silk, raw.
335. " " "
336. " " "
337. " " "
339. Silk, cocoons, Antakir.
340. "
341. " La Canée.
342. " Yanina.
343. " "
344. " Monastir.
345. Silk, Monastir.
346. " Salonique.
347. " Government.
348. " Smyrna.
349. " Konieh.
350. " "
351. " Salonique.
352. " "
353. " "
354. " La Canée.
355. " Yanina.

356. Silk, Yanina.
357. " "
358. " "
359. " Bigha.
360. " "
361. " Yanina.
362. " Diarbekir.
363. " Yskeep.
364. " Valoma.
365. " "
366. " Konieh.
367. " Yanina.
368. " Samos.

AUSTRALIA, QUEENSLAND.

369. Silk. Cocoons, Japanese worm.
370. " European "

SPAIN.

371. Silk.
372. "
373*a*. "

BRAZIL.

374. Silk.
375. " Raw.

EGYPT.

375*a*. Vegetable fibres, Silk of the Gamphocarples fruit.

CLASS 11. COTTON ON THE STEM, IN THE BALL, AND GINNED; ALSO COTTON AND FIBRE SEEDS.

EGYPT.

376. Cotton.
377. "
378. "
379. "
380. "
381. "
382. "
383. " Aschmuni.
384. " "
385. " "
386. " "
387. " "
388. " "
389. " "
390. " "
391. " "
392. " "
393. " "
394. " "
395. " "
396. " "
397. " "
398. " "
399. " "
400. " Mako.
401. " "
402. " "
403. " Hindi.
404. " Sciubra.
405. Cotton and cotton seed, Monteray.
06. " " " " Indian.
407. Cotton seed, Indian.
408. Cotton seed. Ash Muni.
409. " " America.
410. " "
411. " "
412. " "

SOUTH AMERICA, BRAZIL.

413. Paina of Chorisa speciosa.
414. " " "
414*a*. " " "
415. Cotton.
416. " S. Paulo.
417. " Pernambuco.
418. " "
419. " Matto Grosso.
420. " Porahyba.
421. " Bemposta.
422. " "
423. " "
424. " Moranhuo.
425. " Ceara.
426. " Rocha Leao.
427. " Rio Grandi del Nort.
428. "
429. " Cotton seed, S. Paulo.
430. " " " Bemposta.

MEXICO.

431. Cotton, Algodon, Pachuea.
432. " " Cuantha.
433. " " Morelia.
433*a*. " " "

434. Cotton, Algodon, Guerrero Rio Conhuila.
435. " " San Luis Potosi.
436. " " Saltillo.
437. " " Oaxaca.
437*a*. " " "
438. " " Pachuca.
438*a*. " " "
439. " " Campech.
440. " " Merida.
441. " " Ceiba.
441*a*. " " "
441*b*. " " "

RUSSIA.

442. Cotton seed, Ag. Museum Univ. of Domains.
443. " " " " "
444. " " " " "
445. " " " " "
446. " " " " "
447. " " Sea Islands.
448. " Buttons, Ag. Museum Univ. of Domains.
449. " Samarkand.
450. " Kokan.
451. "
452. " Ag. Museum Univ. of Domains.
453. " Kokan.
454. " Katta Uranchy.
455. " Buchana.
456. " Sea Island, Samarkand.
457. " 1st qual. "
458. "

TURKEY.

459. Cotton.
460. "
461. " Bagdad.
462. " Kennyek.
463. " Monastir.
434. " Bagdad.
465. " Yanina.
466. " Dalatmas.
467. Maidos cotton.
468. Polatanas cotton in bolls.
469. Aleppo " "
470. Yanina "
471. Diarbekir cotton.
472. Cotton.

INDIA. NETHERLANDS COLONIES.

473. Cotton with seed.
474. Vegetable fibres.
475. " "
476. " "

FIJI ISLANDS.

477. South Sea Island Cotton.
478. " " " "

AUSTRALIA, QUEENSLAND.

479. Cotton.
480. "
481. " No. 2.
482. "
483. " No. 1.
484. " "
485. " No. 2.

KANSAS.

486. Cotton.

CHINA.

487. Cotton seed, Hupeh Prov.
488. " " Shantung Prov. value at Chefoo $0.08 pe sample.
489. " " Chehkiang Prov. for making oil. Valued at Ningpo $3.00 per pecul.
490. " White.
491. " Yellow.

EGYPT.

492. Jute fibre seed.
493. Aralia papyrifera.
494. Broussouetia.
494*a*. Ramieh Fibre.

CLASS 12. CEREALS (WHEAT, RYE, OATS, ETC.), WITH THEIR PRODUCTS.

CHINA.

495. Wheat, Shantung Prov.
496. Wheat, Tamsui Dist.
497. " Kiangse.

498. Wheat, Newchwang.
499. " Shantung Prov.

CAPE OF GOOD HOPE.

500. Wheat, 1st qual.
501. "

CANADA.

502. Wheat, Highgates.
503. " Manitoba.
504. " Pr. Ed. Island.
505. " Manitoba.
506. " Ontario.
507. " Spring.
508. " Nova Scotia, Lost Nation.
509. " Nova Scotia Spring.

CHICAGO BOARD OF TRADE.

510. Wheat, white winter.
511. " Spring.
512. " N. W. Spring.
513. " Red winter.
514. " N. W. Spring.
515. " " "
516. " Spring.
517. " Rejected spring.

DENMARK.

518. Wheat, Champion.
519. " Hallet's white.
520. " Hickling's prolific.
521. " Kolbcheode.
522. " Spalting's prolific.
523. " Manchester.
524. " Falveria.
525. " Kentish red.
526. " Full measure.

EGYPT.

527. Wheat, 1st qual.
528. " Gharbijeh.
529. "

FRANCE.

530. Wheat, Golden drop.
531. " Algeria.
532. " Clear.
533. " Brown.
534. " Algeria.
535. "
536. " de Hernon.
537. "
538. "
539. Wheat, Kissengland.
540. "
541. "
542 to 570*e*. A collection of samples of Wheat from Victoria.

NETHERLANDS COLONIES. GUELDERLAND.

571. Wheat, red bunch.
572. " smooth eared.
573. " red.
574. " smooth eared.
575. " red Swedish.
576. " rugged eared.
577. " " "
578. " tough.
579. "
580. " white.
581. " " Polish.
582. " " Bunch.

MEXICO.

583. Wheat, Frigo de Guanajuato.

NORWAY.

584. Wheat, Spring heavy.
585. " Winter, 1875, "
586. " " "

RUSSIA.

587. Wheat, Kazan, Model farm.
588. " " " "
589. " Pleghin.
590. " "
591. " "
592. " " 1st qual.
593. " " extra.
594. " "
595. " Bell.
596. " Nostilz.
597. " "
598. " Maltzoff extra.
599. " Tablotzky Dessetovsky.
600. " Tablotzky "
601. " Dookhinoff.
602. " Petrovsky.
603. " Obralnoff.
604. " Odessa Exchange Com.
605. " " " "
606. " " " "
607. " " " "
608. " " " "

609. Wheat, Dyokhinoff.
610. " Ermoloff.
611. " Kobzareff.
612. " Levchin.
613. " Plechanoff, extra qual.
614. " Firsoff, " "
615. " "
616. " Ookhin.
617. " Shotiloff.
618. " Stichensky.
619. " Vassiltchikoff.
620. " "
621. " Vickberg.
622. " "

SPAIN.

623. Wheat, Frigo.
624. " "
625. " "
626. " " Alaza.
627. " " Alonso.
628. " " "
629. " " "
630. " " "
631. " " Caudeal.
632. " " "
633. " " Esquivel, No. 1.
634. " " "
635. " " Macolo.
636. " " Var Neyro.
637. " " Kylebery.
638. " " Pichi.
639. " " Raspebianco.
640. " " " 2d qual.
641. Black Wheat, Sarria (Provencia de Lugo).
642. Wheat, Frigo, Ucgrillo im Varipa.
643. " Frigo, Ucgrillo im Varipa.
644. " Frigo, Verdial.

SWEDEN.

645. Wheat, Kolbchoede.
646. " Clear.
647. " 2d qual.

TASMANIA.

648. Wheat, Archer, W. D. Longford.
648a. " " " "
649. " Red Tuscan, Creswell, C. F.
650. " Golden Crop, Creswell, C. F.
651. " Purple straw, Creswell, C. F.
652. Wheat, Red Lamas, Creswell, C. F.
653. " Farmer's Friend, Creswell, C. F.
654. " Goldsmith.
655. " —— Gibson, W.
656. " Winter Braemar Velvet, Hogarth, D., Launcestown.
657. " Lamont's Prolific, Kemp, G. A., Upper Bagdad, 1875.
658. " Armstrug's Prolific, Kemp, G. A., Upper Bagdad, 1875.

TUNIS.

659. Wheat, medium quality.

TURKEY.

661. Wheat, from Adana (fair).
662. " " Andunoples.
663. " " An Gora.
664. " " Candie (crile).
665. " " " (criss).
666. " " La Canée.
667. " " " "
668. " " Cahil.
669. " " Diarbekir, extra long and heavy.
670. " " Diarbekir, extra long and heavy.
671. " " Dardanelles, 1st quality.
672. " " Dardanelles, 2d quality.
673. " " Erzeroum, 2d quality,
674. " " Konoo.
675. " " Monastir.
676. " " "
677. " " "
678. " " Sivas, extra quality.
679. " " Smyrna.
680. " " Yanina.
681. " " " 1st qual.
682. " " " 2d qual.

MEXICO.

684. Wheat, Frigo.
685. " " de Puebla.
686. " " "

NETHERLANDS COLONIES. ZEELAND.

687. Wheat, Canada.
688. " Chiddaw.
689. " Hallett's white Pedigree.

690. Wheat, Hunter's white.
691. " Macklenburgh.
692. " Rough chaffed, Essex.
693. " Rivet's Bearded.
694. " Summer.
695. " Taunton Dean.
696. " Walchwrern.
697. " White square-headed.
698. " Zeeland.
699. " Brazil.
700. " " "
700a. " "

CANADA.

701. Rye, Nova Scotia.
702. " Barley oats.
703. " Fall rye.

CHICAGO.

704. Rye, Chicago Board of Trade, No. 1.
705. " " " " No. 2.
706. " " " "Rejected.

DENMARK.

707. Rye, Campen.
708. " Eldenaur Bastard.
709. " Graf Valdersdorff.
710. " Jerusalenes.
711. " Swedish Land.
712. " Vaja Land.

FRANCE.

713. Rye, Single, 36 Hectolitres de Sigle.

GUELDERLAND.

714. Rye, Great Rije.
715. " Zeeland Rije.

NORWAY.

716. Rye, Summer.
717. " Winter.
718. " "
719. " " 1875.

RUSSIA.

720. Rye.
721. " Bell.
722. " Dookhinoff.
723. " Kazan Model Farm.
724. " " " "
725. " Novossiltseff.
726. " "
727. " "
728. Rye, Odessa Exchange Committee.
729. " Vassiltchikoff.
730. " Vicksburg.
731. " "
732. "

SWEDEN.

733. Rye, Extra quality.
734. " " Host Rag.
735. " 1st quality.
736. " 2d "
737. " 3d "
738. " early common, No. 11.
739. " early.
740. " hardy.
741. " hulled.
742. " long eared.

TURKEY.

743. Rye, Cus Kun.
744. " Monastir.

ZEALAND.

745. Rye.
746. "
747. " New Giant.
748. " Probster.

CHINA.

749. Millet, Newchwang.
750. " Shantung Prov., value at Chefoo 7 cts. per sample 6338.
751. " Manchooria, fr'm Newchwang 6333.
752. " Shantung Prov., value at Chefoo, 4 to 7 cts. per sample 6336.
753. " Shantung Prov., value at Chefoo, 4 to 7 cts. per sample 6338.
754. " Shantung Prov., value at Chefoo, 4 to 7 cts. per sample 6339.
755. " Shantung Prov., red six cts. per sample 6335.
756. " Kiangsi Prov., value at Ku Kiang $1.16 to $1.54 per pecul 6345.
757. " Kiangsi Prov., value at Chefoo, 3 cts. per sample 6354.

758. Millet, Prov. of Hupeh, used for food and sowing. Value at Hankow $6.00 per pecul 6511.

UNITED STATES.

759. Millet, Delaware.

FRANCE.

760. Millet, Crefie Rouge.

RUSSIA.

761. Millet, Manyuska Model Farm.
762. " Odessa Exch'nge Committee.

TURKEY.

763. Millet, Diarbekir, large.
764. " Cahif.
765. " Yanina.

ZEELAND.

766. Millet, in the ear.

NETHERLANDS COLONIES.

767a. Variety of Bird seed.

CHINA.

767. Basil seed, Shantung Province.

AUSTRALIA.

768. Millet, Victoria.
769. Barley, "
770. " English, from Mayston, Vic., 56½ lbs. per bushel.
771. " Malt from Melbourne.
772. " " 59¼ lbs. per bushel.
773. " " from Richmond, 58½ per bushel.
774. " " St. Armand, 56 lbs. per bushel.
775. " Campbell's creek, 58½ lbs. lbs. per bushel.
776. " " from Melbourne.

UNITED STATES.

777. Barley. California malt fr'm Bergner and Eugel, Philadelphia.

CANADA.

778. Barley from Canada.

PHILADELPHIA.

779. Barley. Refuse from Bergner & Eugel, used for feed.

BRAZIL.

780. Barley.
781. "

CANADA.

782. Barley, Nova Scotia, four rowed.
783. " Nova Scotia.
784. " Manitoba.
785. " Ontario two rowed.
786. " " six "
787. " Toronto.

CHICAGO.

788. Barley, Board of Trade No. 1.
789. " Board of Trade No. 2.
790. " Board of Trade No. 3.
791. " Board of Trade Rejected.

CHINA.

792. Barley, Pearl, Prov. of Hupeh, 6329. Value at Hankow, $3.00 per pecul.
793. " Prov. of Hupeh. Value at Hankow, $1.00 per pecul, 6325.
794. " Kiangsi Prov. Value at Kinkiang 50 cts. per bushel, 6313.
795. " Kiangsi Prov. Value at Chinkiang $2.50 per pecul, 6315.
796. " Manchuria from Newchwang 6363.
797. " Manchuria from Newchwang 6323.
798. " Pearl, Manchuria, from Newchwang, 6327.
799. " Shantung Prov. Value at Ningpo $18.00 per pecul. 4243.
800. " Pearl, Shantung Prov., value at Chefoo 12 cts. per sample 6328.
801. " Suburbs of Ningpo. Value at Ningpo $1.00 per pecul, 6326.

DELAWARE.

802. Barley, Chevaloir.
803. " Potter's.
804. " Carter's prolific.

DENMARK.

805. Barley, Riis.
806. " Great Bluih.
807. " Long specked six rows.
808. " Kulina.
809. " Yorkshire.

EGYPT.

810. Barley, Upper Egypt.

FRANCE.

810a. Barley.
811. "
812. " No. 1.
813. " Malt.
814. " "
815 " "

NETHERLANDS COLONIES.

816. Barley, Guelderland.
817. " Guelderland, summer.
818. " Guelderland, winter.
818a. " Guelderland.
819. " Guelderland.

NORWAY.

820. Barley, Six rows.
821. " Supposed four rows,

RUSSIA.

822. Barley, Bell.
823. " Deughink,
824. " Korf,
825. " Nostitz,
826. " Novassiltseff.
827. " Black, Novassiltseff.
828. " Odessa Exchange Com.
829. " Petrovska Model farm.
830. " Black, Shatiloff.
831. " Vickburg.
832. " "

NORWAY.

833. Barley, Two Rows.
834. " Hulled Hordeum friforcatum.

SPAIN.

835. Barley, Cebanda Negra.
836. " " Caballar.
837. " "
838. " malt, Cebanda.

SWEDEN.

839. Barley, marked No. 15.
840. " " No. 7.
841. Barley, large grained.
842. " Early.
843. " and oats for feed.
844. Malt, No. 1, marked No. 5.
845. " No. 2, " No. 20.

TASMANIA.

845a. Barley Malt, Wm. Gracie, Hobart Town.
846. " " John Degraves.

AFRICA.

847. Barley, Tunis.

TURKEY.

848. Barley, 2d quality.
849. " Aleppo.
850. " Anonnopies, 1st qual.
851. " Cahif, "
852. " Konia,
853. " "
854. " La Canée,
855. " Salonique,
856. " Volonia,
857. " Yanina, 1st quality,
858. " " "

EGYPT.

859. Barley, Upper Egypt.

NETHERLANDS COLONIES.

860. Barley. Zeeland Chavalier.
861. " " Gumagen Spring.
862. " " Six Rows First.
863. " " Summer.
864. " " Thump Winter.
865. " " Winter.
866. " " Winter.

CANADA.

867. Buckwheat,
868. " Manitoba,
869. " Nova Scotia,
870. " Silver Hulled.

CHINA.

871. Buckwheat, Kiangsi Prov. Value at Hinkiang $2.10 per pecul, 6320.
872. " Value at Hinkiang $2.10 per pecul, 6320.
873. " Value at Hinkiang $2.10 per pecul, 6320

874. Buckwheat, Kiangsi Prov. Value at Chinkiang $2.67 per pecul 6321.
875. " Manchuria from Newchwang, 6318.

DELAWARE.

876. Buckwheat.

EGYPT.

877. Buckwheat.
878. " Spinach.
879. " Hemp Ketmil.

NETHERLANDS COLONIES.

880. Buckwheat, Guelderland, Gray Bunch.
881. " Guelderland.

RUSSIA.

882. Buckwheat, Grotenfeld.

SPAIN.

883. Buckwheat, Brioa.
884. " Fajol.
885. " "

AUSTRALIA.

886. Oats, Victoria.
887. " " from Buangor, 52½ lbs. per bushel.
888. " " Grown at Hopton, soil heavy clay. Yield, 40 bushels per acre. Wt. 48 lbs. per bushel.
889. " " Short oats, 52½ lbs. per bushel.
890. " " 50¾ lbs. per bushel.
891. " " Tattarian oats from Buangor, 47 lbs. per bushel.
892. " " Tartarian oats from Colomski 45 lbs. per bushel.
893. "

BRAZIL.

894. Oats.

CANADA.

895. Oats, Black.
896. " Pr. Ed. Island Bulman Black.
897. " " " Black.

CHICAGO BOARD OF TRADE.

899. Oats, No. 1.
900. " " 2.
901. " Rejected.

DENMARK.

902. Oats, Algier.
903. " Odenbrucher.
904. " Siberian.

DELAWARE.

905. Oats, black Scotch.
906. " Sandy.
907. " Providence.
908. " Scotch potatos.
909. " Beuvisk.

FRANCE.

910. Oats, black.
911. " black, large yield.
912. "
913. " black.
914. " Avoine rouge.
915. " " black.
916. "

GUELDERLAND, NETHERLANDS COLONIES.

917. Oats, Procstein.
918. " big.
919. "
920. " bunch.
921. "

NORWAY.

922. Oats, black.
923. " No. 2.
924. " Potato.
925. " No. 3.
926. "
927. " Kinn Bush.
928. " Mixed barley and oats, 102 Holland lbs.
929.

RUSSIA.

930. Oats, Ermoloff.
931. " Shatiloff.
932. " Odessa Exchange Committee.
933. " Shatiloff.
934. " Vassellchikoff, R. W.
935. " Dookhinoff.
936. " Bell.
937. " Fareoff.
938. " Kazan Model farm.

939. Oats, Novossiltseff.
940. " Dookhinoff.
941. " Kazan Model farm.
942. " Leochin.
943. " Stichinsky.
944. " "

SPAIN.

945. Oats, Avena.
946. " "
947. " "

SWEDEN.

948. Oats, No. 3.
949. " Hulls.
950. " Mixed grain.
951. "
952. "

TASMANIA.

953. Oats, Poland.
954. " Tartarian.
955. " " "

TURKEY.

956. Oats, Cainée.
957. " Yanina, 1st qual.
958. " "
959. " Kus Kuri.
960. " Bevat.
961. "

ZEELAND, NETHERLANDS COLONIES.

962. Oats, Heavy Groningen.
963. " Frisian.
964. " Winter.
965. " Black Tartarian.
966. " Danish.
967. " Probster.

BRAZIL.

970. Rice, unhulled white.
971. " " yellow marked 1040.
972. " Hulled, extra, marked Maranhou.
973. " Marked Moranhou, 1043.

CHINA.

974. Rice, Black roasted and taken as coffee, South Formosa.
975. " 2d qual., " "
976. " 3d crop.
977. " Tamsui district.
978. "
979. Rice, 2d crop, suburbs of Ningpo.
980. " 3d " " "
981. " Tamsui district.
982. " " "
983. " Shangtung Prov.
984. " Unshelled, 2d crop, suburbs of Ningpo.
985. " 1st qual., South Formosa.
986. " Paddy, Kiangsi Prov.
987. " " Tamsui district.
988. " 1st crop unshelled, suburbs of Ningpo.
989. " 3d qual., South Formosa.
990. " " " "
991. " Paddy, Tamsui district.
992. " 2d qual., Kiangsi Prov.
993. " Paddy, Tamsui district
994. " 2d qual., Fukien Prov.
995. " Red, South Formosa.
996. " Tamsui district.
997. " 2d crop unshelled. Suburbs of Ningpo.
998. " 1st qual., Kiangsi Prov.
999. " Paddy, Tamsui district.
1000. " " " "
1001. " Kiangsi Prov.
1002. " " "
1003. " 3d crop unshelled. Suburbs of Ningpo.
1004. " Tamsui.
1005. " unshelled, Prov. of Foochow
1006. " Suburbs of Ningpo.
1007. "

EGYPT.

1008. Rice barley.
1009. " cleaned.
1010. " barley.

MEXICO.

1011. Arroy de Yucatan, unhulled rice.

TURKEY.

1012. Variety of rice.

HAWAIIAN ISLANDS.

1013. Rice, unhulled.
1014. " hulled, No. 1.
1015. " " " Chaleur Plantation.
1016. " " No. 2. " "
1017. " " No. 1. Wiahole Plantation.

INDIA, NETHERLANDS COLONIES.

1018. Rice, on the stalk.
1019. " " " marked 119.
1020. " " " marked 120.
1021. " " " marked 121.
1022. " " " marked 122.
1023. " " " marked 123.
1024. " Shelled, marked 124.
1025. " Red, shelled, marked 125.
1026. " Black, " " 126.
1027. " White, " " 127.
1028. " " " " 128.
1029. " " " " 129.
1030. " " " " 130.
1031. " Unshelled " 131.
1032. " Shelled " 132.

SPAIN.

1037. Rice, Arroz Cilindrad.
1038. " " "
1039. " " "
1040. " " "

MEXICO.

1041. Rice, Arroz de Puebla.

CHINA.

1042. Rice, Shantung Prov. Basil seed.
1043. Maize, Kiangsi Prov.
1044. Corn, Prov. of Hupeh. Value at Hankow $3.00 per pecul. 6330.
1045. " Manchuria from Newchwang, Maize, 6347.
1046. " Manchuria from Newchwang, Maize, 6346.
1047. " Suburbs of Ningpo. Value at Ningpo $1.50 per pecul.
1048. " Shangtung Prov. Value at Chefoo 4 cts. per sample. 6348.
1049. " Shantung Prov. Value at Chefoo 4 cts. per sample. 6349.
1050. " Small yellow.

CHICAGO BOARD OF TRADE.

1051. Corn, No. 1.
1052. " " yellow.
1053. " " white.
1054. " No. 2.
1055. " New high mixed.
1056. Corn, new mixed.
1057. " Rejected.

DELAWARE.

1058. Corn, Adams extra.
1059. " Yellow, known as Canada.
1060. " Extra early.
1061. " Tuscarora.
1062. " Early sugar.
1063. " Ground seed.
1064. " White Flint.

EGYPT.

1065. Corn, Naire Maize.
1066. " Pearl "

MEXICO.

1067. Corn, Maize de Yucatan.

SPAIN.

1068. Corn.
1069. " Encarnado de Francia.
1070. " Maiz perla blanco.
1071. " Maiz perla inferior.
1072. " Maiz amorillo de la perla.

RUSSIA.

1073. Corn, Maize Denyhink red.
1074. " " " yellow.
1075. " Odessa Exchange Com.

TURKEY.

1076. Corn, Andrinoples, 1st qual.
1077. " Canée.
1078. " Catril.
1079. " Dardanelles.
1080. " Hidgar.
1081. " Volonia Maize.
1082. " Yanina.

BRAZIL.

1083. Flour of Mandioca.
1084. " " "
1085. Farinha de "
1086. Scraping of " powdered.
1087. Starch of "
1088. Fecula.
1089. Corn meal.
1090. From corn.
1091. Prepared corn.
1092. Starch.
1093. Tapioca, F[illegible]ad.
1094. [illegible]ot.
1095. marked 818.

1096. marked 817.
1097.
1098. " 179.
1099. " 816.
1100. " 792.

CHINA.

1101. Wheat flour, Shantung Prov.
1102. Macaroni, " "
1103. Vermicelli, Newchwang.

CANADA.

1104. Oatmeal, Mount Forest.
1105.

GLEN COVE, N. Y.

1106. Duryea's Satin Gloss Starch.
1107. " " " "
1108. " Improved Corn Starch.
1109. " Maizena.

HAWAIIAN ISLANDS.

1110. Tapioca.
1111. Farina.
1112. Arrow root.
1113. " "

OSWEGO, N. Y

1114. Corn-Starch for culinary use.
1115. Blue Starch.
1116. Silver Gloss Starch.
1117. Refined Corn-Starch.
1118–1120. Varieties of starch.

NETHERLANDS.

1121. Flour, Meal, &c.
1122. " " "
1123. " " "
1124. " " "
1125. " " "
1126. " " "
1127. " " "
1128. " " "
1129.

SPAIN.

1130. Afreitas.

SWEDEN.

1131. Nafu-gryn. 2 gauger krossode.
1132. Rag-mjol.
1133. Wheat Bran.
1134. Rag-mjol.
1135. Nafu-gryn.
1136. Hafregryns mjol (affan).
1137.

TURKEY.

1138. Bulbed Selep (a starchy food).

TASMANIA.

1139. Flour from Tasmania.

CLASS 13. PLANTS USED FOR FOOD OTHER THAN CEREALS, (PEAS, BEANS, ETC.).

AUSTRALIA.—VICTORIA.

1140. Beans, long pod; the best yielding variety known; from Geelong.

BRAZIL.

1141. Beans.
1142. " speckled.
1143. " Castor Oil.
1144. " red mixed.
1145. " "
1146. " white flat.
1147. " " common.
1148. " " sweet early.
1149. " light silver "Carana," 1020.
1150. " dark silver, small.
1151. " light gray, 1017.
1152. " " very small.
1153. Beans, yellow.
1154. " yellow, small.
1155. " reddish yellow.
1156. " red, 1004.
1157. " long mixed, 1005.
1158. " brown.
1159. " " small.
1160. " " Parana, 1014.
1161. " brown.
1162. " dark mixed.
1163. " yellowish, 1018.
1164. " reddish, 1007.
1165. " large yellow, 1018.
1166. " reddish medium.
1167. " horse.
1168. "
1169. " spider, 1048.
1170. " black, 1009.

1171. Beans, black, medium, 1015.
1172. " " "
1173. " black, small, 1019.
1174. "

CANADA.

1175. Beans, Montreal White Pea.
1176. " Nova Scotia Purple speckled Bush.
1177. " " " Dunclourd Bush.
1178. " " " Yellow-eyed Bush.
1179. " " " Dwarf China Bush.
1180. " " " Pole.
1181. " " " Royal pale.
1182. " " " Fawn.
1183. " " " Robin's egg Bush
1184. " " " Provincial.
1185. " St. Janvier Early Brown.
1186. " Petite Cote H.
1187. " Province Quebec Dwarf Butter.
1188. "
1189. "

CHINA.

1190. Black beans from Formosa.
1191. Large flat green Peas, Kiangsi Province.
1192. Large black Beans, Shantung Province.
1193. Beans, white, suburbs of Ningpo.
1194. " small green, Kiangsi Prov.
1195. " " Shantung "
1196. " " " Kiangsi "
1197. " " Hupeh "
1198. " " Shantung "
1199. " black, Hupeh Prov.
1200. " small green, Newchwang.
1201. " black, Formosa.
1202. " " for rheumatism, Kiangsu.
1203. " white, Shantung Prov.
1204. " yellow, Kiangsi "
1205. " rice, Formosa.
1206. " small black, Shantung Prov.
1207. " white, " "
1208. " black, " "
1209. " yellow, " "
1210. " large black, " "
1211. " " red, " "
1212. Beans, large red, Shantung Prov.
1213. " yellow, Hupeh Prov.
1214. " red, Shantung "
1215. " large, suburbs of Ningpo.
1216. " flat, Kiangsi Prov.
1217. " " " "
1218. " small mixed, Shantung Prv.
1219. " from Newchwang.
1220. " " Kiangsi Prov.
1221. " " Formosa.
1222. " " Kiangsi Prov.
1223. " name unknown, Kiangsi Prov.
1224. " from Newchwang.
1225. " Kiangsi Prov.
1226. " medicine, Newchwang.
1227. " Chefoo.
1228. " Newchwang.
1229. "
1230. "

DELAWARE.

1231. Beans, Mohawk.

EGYPT.

1232. Beans, large white.
1233. " " round.
1234. " speckled butter.
1235. " red kidney.
1236. " Lubia Doliohos.
1237. "
1238. " from lower Egypt.
1239. " (Castor oil) Ricurus plant.
1240. " from Fayoma.
1241.
1242. " Dolichos Lablab.

FRANCE.

1243. Beans, large white.

NETHERLANDS COLONIES, GUELDERLAND.

1244. Beans, Arab short.
1245. " white short.
1246. " " "
1247. " " French.
1248. " "
1249. " yellow.
1250. " brown.
1251. " yellow, short.
1252. " horse.
1253. " " mixed.
1254. " Pigeon.
1255. " spotted short.
1256. " Fretillery.

1257. Beans, salad short.
1258. " white.
1259. " Mottha.
1260. " spotted French.
1261. " Laden big beans.
1262. "
1263. " Frijol de Puebla.
1264. " " " Yucatan red.
1265. " " " " black.

RUSSIA.

1266. Beans, French, Odessa Exchange Committee.
1267. " French, Odessa Exchange Committee.
1268. " French, Manyska model farm.
1269. " French, Manyska model farm common.
1270. " large flat common.
1271. " sweet French.

SPAIN.

1273. Beans, Judias de Garrofa.
1274. " Habas de Manteca.
1275. " Habas Mumda.
1276. " Judias.
1277. " Jubachas blancas.
1278. " Fosols.
1279. " " Jabes.
1280. " " Renegas.
1281. " Judias Renegas senoritas.
1282. " Judias pintadas.
1283. " Chinas.
1284. " Fasols Gabachas.
1285. " Jabas.
1286. " Fasols Reneyas dark.
1287. " Frijoles Americanos.
1288. " Habas negras panesquetas.

SWEDEN.

1290. Beans, yellow.
1291. " brown.
1292. " green, large.

TASMANIA.

1293. Beans, horse. C. F. Creswell.

TUNIS.

1294. Beans, white.
1295. " small black spots.
1296. " large, flat.

TURKEY.

1297. Beans, Adana, Castor Oil.
1298. " Aleppo, small.
1299. " Canée, small.
1300. " Konia, white.
1301. " Pahamar.

NETHERLANDS COLONIES.

1302. Beans, Zeeland.
1303. " large white.
1304. " giant runners.
1305. " white globe.
1306. "
1307. " small white.
1308. " " "
1309. " white dwarf.
1310. " black Pewet.
1311. " brown "
1312. " large speckled.
1313. " brown "
1314. " large brown.
1315. " Pigeon.

GUELDERLAND.

1316. Beans, great.
1317. " " flat.
1318. " Gronnigen.
1319. " Ruiselaer.
1320. " large, mixed.
1321. " sheep.
1322. " Besilian sheep.
1323. " Thump.
1324. " sugar.
1325. "
1326. "
1327. "

AUSTRALIA, VICTORIA.

1328. Peas, Bellevine new fodder.
1329. " Geelong new fodder.
1330. " Bellevine Prussian Blue, crop of 1876.
1331. " Geelong, 1876, Yorkshire head, delicious.

BRAZIL.

1332. Peas, marked 1080.
1333. " Chicaro Parana.
1334. " white.
1335. " small green.

CANADA.

1336. Peas, white.

1337. Peas, young.
1338. " Beauharnois gray.
1339. " Manitoba Field.
1340. "
1341. " " Crown.
1342. " Vandenil Bean.
1343. " Nova Scotia marrow fat.

CANADA.

1344. Peas, Yeudon split.

CHINA.

1345. Peas, Hupeh. Value at Hankow $2.50 per pecul.
1346. " Wuton. Value at Kiukiang $1.46 per bushel.
1347. " large yellow. Value at Chinkiang $2.67 per pecul.
1348. " Kiangsi, small dried. Value at Chinkiang $2.60 per pecul.
1349. " Pharbitis convolvulus. Value at Ningpo $7.00 per pecul.
1350. " Pharbitis seed. Value at Ningpo $7.00 per pecul.
1351. " Kiangsi, Vitexirisen. Value at Ningpo, $8.00 per pecul.

EGYPT.

1352. Peas, chick.
1353. " sugar. Pisum Sativum.
1354. " green crushed.
1355. " from Middle Egypt.
1356. " roasted chick.
1357. " Lupine.
1358. " Vitia Stativa.
1359. " Cyperus Esculentus.

BRAZIL.

1360. Peas.

FRANCE.

1361. Peas, mixed.

NETHERLANDS COLONIES. GUELDERLAND.

1362. Peas, green crown.
1363. " green field.
1364. " " "
1365. " yellow "
1366. " Capucin yellow.
1367. " " brown.
1368. " gray.

NORWAY.

1369.
1370. Peas, gray, early ripe.
1371. Peas, black, for fodder.

RUSSIA.

1372. Peas, Ermoloff.
1373. " Levchin.
1374. " Odessa Exchange Com.
1375. "

SPAIN.

1376. Peas, Melas.
1377. " Attramuces.
1378. " "
1379. " Guijas.
1380. " Titos ó muelas.
1381. " Garbanzoi.
1382. " " not cultivated in U. S.
1383. " quisantes verdes.
1384. " Zeros, (Coresha de 1875.)
1385. " Areponces.
1386. " "
1387. " Galgana.

SWEDEN.

1389. Peas, small white, early.
1390. " white, grown by F. Jacobson.
1391. " green.
1392. " white hvita.
1393. " early green.
1394. " small early green.
1395. " Aker arter (gra).
1396. " black.

TASMANIA.

1397. Peas.
1398. " Field green, Hoodford's, from C. F. Creswell.
1399. " grey, C. F. Creswell.

TUNIS.

1400. Peas, yellow.
1401.

TURKEY.

1402. Peas, Bagdad, early table.
1403. " La Canée, small.
1404. " " "
1405. " Dardanelles, small.
1406. " Konia.
1407. " Smyrna, small.
1408. " Yanina, mixed.
1409. " " "
1410. " " small dark.

NETHERLANDS COLONIES, ZEELAND.

1411. Peas.
1412. " white.
1413. " large blue.
1414. " small blue.
1415. " wrinkled.
1416. " brown.
1417. "

NORWAY.

1418. Tares, Futter Vicias.

RUSSIA.

1419. Tares, Mookhin white.
1420. " " black.
1421. " Kazan Model farm.

SPAIN.

1422. Tares, Leegum.

SWEDEN.

1423. Tares and oats used for feed.

TASMANIA.

1424. Tares, Golden, C. F. Creswell.
1425. "

EGYPT.

1426. Lentils, Gleditshia triatanthos.
1427. " Upper Egypt.
1428. " Bean, upper Egypt.
1429. " Lower "
1430. " Crushed, lower Egypt.
1431. " " " "

RUSSIA.

1432. Lentils, Pearl Deughink.

SPAIN.

1433. Lentils, algarrola.
1434. " Lentejas.
1435. " "

TUNIS.

1436. Lentils.

TURKEY.

1438. Lentils, Adana.
1439. " Kara Hissar.
1440. " Yanina.

RUSSIA.

1441. Carrot, Zapevaloff.
1442. "

FRANCE.

1443. Beet, Betteraves.

RUSSIA.

1444. Beet, Vassiltchikoff.
1445. " Zablotzky Desetovsky.

SPAIN.

1446. Beet.

NETHERLANDS COLONIES, ZEELAND.

1447. Beet, mangold wurzel.

CHINA.

1448. Onion, Kiangsu Prov. Leek, value at Chinkiang, $25 per pecul.

RUSSIA.

1449. Onion, Zapevaloff.

TUNIS.

1450. Onion.

TURKEY.

1451. Onion, Smyrna.

RUSSIA.

1452. Radish.
1453. " Zapevaloff.

EGYPT.

1454. Turnip, etc., Brassica Aveka.
1455. " Mayaus alba.
1456. " " Rays.

DELAWARE.

1457. Turnip, white flat.

TURKEY.

1458. Turnip, Saxonkhan.

SWEDEN.

1459. Cabbage, etc.

RUSSIA.

1460. Cress, Zapevaloff.
1461. Spinach.
1462. Lettuce, Zapevaloff.

EGYPT.

1463. Lettuce.
1464. Parsley, Apsium petroselimun.
1465. Spinach.

RUSSIA.

1466. French grass, Ermoloff.
1467. " " Kharkoo Model farm.

EGYPT.

1468. Endive.

1469. Hibiscus Esculentus as used for soup.
1470. Hibiscus Esculentus as used for pickles.

CHINA.

1471. Seeds, commercial, in paper.
1472. " Gourd. Kiangsi Prov. Value at Amoy $22 per pecul.

EGYPT.

1473. Seeds, Gourd. Rouora Tavuile.
1474. " " Pava "

CHINA.

1475. Seeds, Pumpkin. Shantung. Value at Chefoo 8 cts. per sample, 3846.
1476. " Pumpkin. Kiangsi. Value at Chinkiang $15.50 per pecul.

EGYPT.

1477. Seeds, Pumpkin. Quara Houpi.
1478. " " " Asfur.

RUSSIA.

1479. Seeds, Pumpkin. Zapevaloff.
1480. " Cucumber. "

EGYPT.

1481. Seeds, Melon. Shammam.

SPAIN.

1482. Seeds, Melon. Penitas de Melon de todo cano.
1483. " " Penitas.

EGYPT.

1484. Seeds, Melon, Water.

CHINA.

1485. Seeds, Melon, Water. Newchwang.
1486. " " " Kiangsi Prov. An aperient. Value at Chinkiang $19.44 per pecul.

TURKEY.

1487. Seeds, Melon, Winter. Aleppo.

CLASS 14. NUTS.

CHINA.

1488. Brown Lotus Nuts.
1489.
1490. " " " Hupeh Prov. Value at Hankow $6.00 per pecul.
1491. White Lotus Nuts.
1492. Salisbereau Seed. Value at Chefoo 11 cts. pecul. Hupeh.
1493. White Nuts for food. Value at Hankow $1.50 per pecul.
1494. Hazel Nuts from Newchwang.

RUSSIA.

1495. Chestnuts from Crimea, Swokhin.
1496. " Povudooks, Swokhin.

CHINA.

1497. Chestnuts. Shantung. Value at Chefoo 12 cts. per sample.
1498. Peanuts. Shantung. Value at Chefoo 17 cts. per sample.

EGYPT.

1499 Peanuts.

SPAIN.

1500. Peanuts. Cacahuet, Mani.
1502. Pinones in shell.
1503. " shelled.

BRAZIL.

1504. Sapucaia Nuts.
1505. Almendras Blamadas del Vale, seed imported from Spain.
1506. Almendra Fina.
1507. Walnuts.

SPAIN.

1508. Walnuts.

CHINA.

1509. Nuts. Chêhkiang.
1510. Apricot kernels. Hupeh. Value at Hankow $7.00 per pecul.

RUSSIA.

1511. Succory. Swokhin, to adulterate coffee.

EGYPT.

1512. Hibiscus Esculentus. Chufas.

SPAIN.

1513. Chufas.
1514. "

CLASS 15. FLESHY FRUITS (DATES, APRICOTS, ETC.).

EGYPT.

1515. Feronos Elephantum.

CHINA.

1516. Jujubes, red. Shantung Prov. Value at Chefoo 3 cts. per sample.
1517. " black. Value at Chefoo 4 cts. per sample.

SPAIN.

1518. Walnuts.

EGYPT.

1519. Melia Azedarach.
1520. " "

SPAIN.

1521. Higos blancos o' de cofin.

EGYPT.

1522. Apricot paste.
1523. Preserved dates from the Oasis.
1524. " "
1525. Phœnix Dactylifera Volum.
1526 " " "
1527. " " da gumma.
1528. " " gondula.
1529. " " ibriny.
1530. " " shâmi.
1531. " " "
1532. " " yarroutis.
1533. Ceratnia siliqua.

SPAIN.

1534–1537. Castanas.

CLASS 16. THEIN PLANTS, (TEA, COFFEE, COCOA, ETC.).

BRAZIL.

1538–1547. Coffee.
1548. Coffee, Bahia.
1549. " " mixed.
1550. " Bemposta.
1551. " "
1552. " "
1553. " " Augusto Sovres.
1554. " " " "
1555. " " choice.
1556. " with and without husk.
1557. " Augusto, Sovres.
1558. " Unhulled.
1559. " "
1560. " Brunido Cantagallo.
1561. " Cantagallo.
1562. " "
1563. " Brunido Cantagallo.
1564. " Crogueira da gama.
1565. " Corovellas.
1566. " Cantagallo, Rio de Janerio.
1567. " Despolpado.
1568. " Dommgos, Rio de Janerio.
1569. " Exhibition Committee, Vienna.
1570. " Exhibition Committee, Rio de Janerio.
1571. " Eucreo.
1572. Coffee, Fezueda de Triumpho.
1573. " Lavoda.
1574. " Rio de Janerio.
1575. "
1576–1579. Rocha Leao.
1580. " Rodrigeus Jordao.
1581. " Supelped.
1582–1585. San Paulo.
1586. " Vergueiro.
1587. "

HAWAIIAN ISLANDS.

1588. Coffee, Kona.
1589. " "

MEXICO.

1590. Coffee. Café de Colima.
1591. " " de Cordoba.
1592–1595. Coffee. Café de Uruapan.

INDIA, NETHERLANDS COLONIES.

1596–1654. Coffee, Netherlands Catalogue, Nos. 59–116.

RUSSIA.

1655. Coffee. Barley, Sivokhin.
1656. " Acorn, "
1657. " " "

BRAZIL.

1658–1661. Cocoa.
1662. Cocoa. Dipterius odorator.
1663. "
1664. "

EGYPT.

1665. Tamarind husks.
1666. " "
1667. Pongamia glabra.
1668. " "
1669. Acacia nilotica.
1670. Ceratonia Siliqua.

CLASS 17. SACHARINE SEEDS AND SUBSTANCES.

CHINA.

1672. Sorghum, Kiangsi Prov. Value at Chefoo 2 cts. per sample.
1673. " Kiangsi Prov. Value at Kiukiang $1.50 per pecul.
1674. " Heupeh. Value at Hankow $1.50 per pecul.

TUNIS.

1675. A seed resembling sorghum.

AUSTRALIA, QUEENSLAND.

1677–1682. Sugar.

BRAZIL.

1683. Sugar, Ceara.
1684. " "
1685–1697. Sugar, manufactured at Campos Rio de Janerio.
1698–1709. Sugar, manuf., Pernambuco.

CHICAGO BOARD OF TRADE.

1711. Sugar, Beet, 1st product.
1713. " " 3d "

HAWAIIAN ISLANDS.

1714–1727. Sugar.

INDIA. NETHERLANDS COLONIES.

1728–1735. Sugar.

CLASS 18. AROMATICS, (ANISE, DILL, ETC.).

ALGERIA. FRENCH COLONIES.

1737. Hops.

AUSTRALIA, VICTORIA.

1738. Hops, from the aboriginal station Corrandeuk.
1739. " California, from Bergner & Engel, Brewers, Phila.
1740. " best Bavarian, from Bergner & Engel, Brewers, Phila.
1741. " New York, from Bergner & Engel, Brewers, Phila.

FRANCE.

1742. Hops. Burgundy.
1743. " Lorraine.
1744. "

RUSSIA.

1746. Hops. Bohemia.
1747. " "

TASMANIA.

1748. Hops, Golden.
1749. " known as No. 49.

SPAIN.

1750. Cauamones.
1751. "

TURKEY.

1752. Anise seed, from Mardis.
1753. " " " Aleppo.
1754. " " " Dardanelles.

SPAIN.

1755. Anise seed.

TUNIS.

1756–1759. Anise seed.

UPPER EGYPT.

1760–1762. Anise seed.

NETHERLANDS COLONIES. ZEELAND.

1763. Caraway.

RUSSIA.

1764. Dill. Zapevaloff.

TUNIS.

1765. Coreanda.

EGYPT.

1766–1768. Coriandrum Sativum.

SPAIN.

1769. Pimento de Naboo.

CHINA.

1770. Clove Tree seed.
1771–1772. Cloves.

INDIA, NETHERLANDS COLONIES.

1773–1775. Pepper, white.
1776–1779. " black.

EGYPT.

1781–1782. Pepper, red, Capsicum annuum.

INDIA, NETHERLANDS COLONIES.

1783. Chile Mulato.
1784–1789. Mace.

CLASS 19. OLEAGINOUS SEEDS, (FLAX, RAPE, DILL, ETC.).

CHINA.

1790. Seed of a plant, Syschuen Prov.

CANADA, NOVA SCOTIA.

1791. Flaxseed.
1792. " Varrennov.

FRANCE.

1793–1794. Flaxseed.

GUELDERLAND.

1795. Flaxseed.
1796. " Crop of 1875. Direct importation from Riga at Rotterdam.
1797. " Crop of 1875. White blossom, Dutch.
1798. Flaxseed.

RUSSIA.

1799. Flaxseed.
1800. " Bessarabian Horticultural School.
1801. " Pskor Statistical Com.
1802. " Haramycheff.
1803. " Kazan Model Farm.
1804. " Obrainoff.
1805. " Odessa Exchange Com.
1806. " Dootchmoff.
1807. " Repuin Princek.
1808. " Oil Press Pskor Statistical Com.
1809. " Pleshanoff.

SPAIN.

1810. Linaza.
1811. Flaxseed.
1812. "

SWEDEN.

1813. Flaxseed.

TASMANIA.

1814. Flaxseed, from C. F. Creswell.

TUNIS.

1815. Flaxseed.

TURKEY.

1816. Flaxseed from Tutours.

ZEELAND.

1817. Flaxseed.

GUELDERLAND.

1818. Lin Meal.

RUSSIA.

1819. Linseed Oil Cake.

CHINA.

1820–1822. Sesamum seed.
1823. Small Pine "
1824. Mustard "
1825. Sin "
1826. Cabbage "
1827. Castor oil beans.
1828. " " "
1829. Large pine seed.
1830–1833. Sesamum seed.

RUSSIA.

1834. Canary seed.

FRANCE.

1835. Canary seed, from Algeria.

ZEELAND.

1836. Canary seed.

BRAZIL.

1837. Mustard.

ZEELAND.

1838. Yellow mustard.

RUSSIA.

1839. Sunflower seed. Bessarabian Horticultural School.

TURKEY.

1840. Sunflower seed, white, fr'm Aleppo.

SPAIN.

1841. Sunflower seed. Alazor.

EGYPT.

1842. Sunflower seed. Carthamus.
1843. " " "
1844. Pistacia therebintus.
1845. Poppy.
1846. Lactuca Oleifera.
1847. Rape seed.
1848. " "
1849. White Rape.
1850. Sesame.
1852. Mustard.

FRANCE.

1853. Camelina.
1854. Colza seed.

GUELDERLAND.

1855. Rape seed.

RUSSIA.

1856. Rape seed.
1857. " "
1858. Camline seed.
1859. Rape "
1860. " " wild.

SPAIN.

1861. Semilla de madia sativa.

TURKEY.

1862. Oilseed.

TASMANIA.

1863. Rape seed.

ZEELAND.

1864. Winter rape.
1865–1868. Oilseed.

CLASS 20. FORAGE PLANTS, (CLOVER, HAY, ETC.).

DELAWARE.

1869. Red Clover.

NORWAY.

1870. Red Clover.

RUSSIA.

1871. Clover seed.
1872. " "
1873. " " Kazan Model farm.

SWEDEN.

1874. Clover seed.

TASMANIA.

1875. Perennial Red Clover.
1876. White Clover.

RUSSIA.

1877–1880. Timothy seed.
1881. Kazan Model farm.

SWEDEN.

1882. Timothy seed.
1883. " "
1884. Grass seed.

NORWAY.

1885. Mixed grass seed.
1886. Timothy seed.

DELAWARE.

1877. Timothy seed.

TASMANIA.

1888. Italian Rye-grass seed.
1889. Rape grass seed.

EGYPT.

1890. Cress seed.

AUSTRALIA.

1891. Red grass seed.

FRANCE.

1892. Minette.

DELAWARE.

1893. Hungarian grass seed.

RUSSIA.

1894. Lucerne.

CHINA.

1895. Lucerne.

RUSSIA.

1896. German Mohair.
1897. Mohair.

TASMANIA.

1898. Lucerne.

EGYPT.

1899. Melilotus.
1900. "

SPAIN.

1901. Mijo.

SWEDEN.

1902. Klofver-fro.

1903. Mixed Clover.

RUSSIA.

1904. Spurry.
1905. " Kazan Model farm.

CHINA.

1906. Knot Grass.

CLASS 21. GUMS, RESINS, ETC.

BRAZIL.

1907. Acacia angico.

EGYPT.

1908. White gum.

INDIA.

1909–1911. Crude gums.
1912–1915. Refined wax.

MEXICO.

1916. Campeche wax.

NETHERLANDS COLONIES IN INDIA.

1917–1922. Rubber.

BRAZIL.

1923. Rubber.

QUEENSLAND, AUSTRALIA.

1924. Glue.
1925. Prepared strings for musical instruments.

BRAZIL.

1926. Glue.

CLASS 22. MEDICINAL PLANTS.

INDIA.

1927. Medicinal preparations.

CHINA.

1928. Opium, native. Value at Hankow, $340.00 per pecul.
1929. The fruit of a tree, a medicine. $11.50 per pecul.
1930. Rice roasted and prepared as coffee (not ground) to assist digestion.
1931. A tonic and cooling medicine. $11.00 per pecul.
1932. Cassiatora seed for Ophthalmia. $12.00 per pecul.
1933. A stomachic. $7.00 per pecul.
1934. A tonic and astringent. $13.00 per pecul.
1935. Leek seeds for neuralgia. $5.00 per pecul.
1936. Poison. $14.00 per pecul.
1937. A tonic and antirheumatic. $11.50 per pecul.
1938. Caterpillar for bronchial complaint. $11.00 per pecul.
1939. Cyperus esculentus, a stimulant. $9.00 per pecul.
1940. Cassia sophora bud, a tonic and astringent. $6.80 per pecul.
1941. Scrophularia seed, a stimulant. $5.00 per pecul.

EGYPT.

1942. Fraxinus ornus.
1943. Senna.

INDIA. NETHERLANDS COLONIES.

1944–1951. Medicinal.

MEXICO.

1952. Copal de pudra.
1953. Copalchi. Croton pseudo china.
1954. Lengua de Ciervo. Polypodium lanceolatum.
1955. Artèmina Mexicana Estafiata.
1956. Semillas de balsamo. Mysospermum.
1957. Yerba de la Puebla.
1958. Yerba dulce. Lippia dulcis.
1959. Zempoalxochitt. Zagetes Mexicana.
1960. Yerba del Negro. Malva angustifolia.
1961. Te de milpas. Bidens tetragona.
1962. Prodigiosa. Athanaria amara.

1963. Bonplandi.
1964. Yerba del Cainc. Gomphrena procumbens.
1965. Gayuba. Arctostaphylos pungens.
1966. Semillas de cominos nerticos. Thapsia asclepium.
1967. Nanchalahua. Erythrea Sticta.
1968. Palo del Muerto. Ipomœa Mumucoides.
1969. Raiz de Yesgos Urtica Mexicana.
1970. Calayuala. Polypodium aureum.
1971. Tripa de Judas. Cissus tiliacea.
1972. Contrayerba. Dorstenia contrayerva.
1973. Crytrina coralodendrum.
1974. Linaloe de Mexico.
1975. Cana festula. Cassia brasiliensis.
1976. Colancapatli. Solidago Montana.
1977. Salvia Beal. Buddleia globosa.
1978. Mispatle. Buddleia verticillata.
1979. Hachinol. Heimia salicifolia.
1980. Cebadilla. Veratrium cevadilla.
1981. Atlanchana. Cuphea lanceolata.
1982. Dictamo Real. Marrubium pseudo dictamus.
1983. Tacopatle. Aristolochia Mexicana.
1984. Peonia Mexicana. Cyperus rotundus.
1985. Ahuehueti. Taxodium distichum.
1986. Jamaica. Hibiscus sabdarifa.
1987. Yerba del Anel. Eupatorium sanctum.
1988. Gengibre Zingiber officinalis.
1989. Crameria pauciflora.
1990. Raiz del Yndio. Aristolochia fœtida.
1991. Fecula del Jatropha edulis.
1992. Acido Pipitzhoic estrado del fixis pipitzahoac.
1993. Tarilla. Senecio vernus.
1994. Gobunadora de Mexico. Zigophillum fabago.
1995. Tepozan. Buddleia Americana.
1996. Capulin. Cerasus capollin.
1997. Té limon. Andropogon citratus.
1998. Picosa. Croton ciliatum glandulosum.
1999. Cedron. Aloysia citriodora.
2000. Arrayan. Myrtus arrayan.
2001. Yerba del Zorrillo. Croton dioicus.
2002. Flor de Sauso. Sambucus Mexicanus.
2003. Contrayerba. Dorstenia Contrayerva.
2004. Codo de Fruile. Fevetia icotli.
2005. Gordolobo del Pais. Gnaphalium canescens.
2006. Cunpinole. Ambar Mexicana.
2007. Valeriana Fotucana Collasatelus.
2008. Semillas de Curcas purgans.
2009. Sudda Consuelda. Potentilla multifida.
2010 Goma del mangle. Rizophora.
2011. Yncienso de Mexico.
2012. Goma de Sonora. Mimosa lacifocra.
2013. Recina del schinus molle mejico.
2014. Goma de Mesquita. Inga circinalis.
2015. Pimienta de Tabasco. Myrtus pimenta.
2016. Cortezia de Cuachalalate Rajania.
2017. Semilla de Ticama. Jolichos tuberosus.
2018. Cuayiote. Rhus perniciosa.
2019. Frittos dela Bixa Orellana.
2020. Toloxochitl. Magnolia Mexicana.
2021. Resina del Achras Zapota.
2022. Doradilla, Lycopodium nidiformis.

RUSSIA.

2023. Poppy seed, Manywska Model Farm.

CAPE OF GOOD HOPE.

2024. Prairie Damask leaves.

TASMANIA.

2025. Eucalyptus Globulus or blue gum. Prevents fever where sown.

EGYPT.

2026. Poppies cut for the opium.
2027. Tamarind cakes from Darfoor.
2028. " " " "

CHINA.

2029-2041. Tobacco.
2042. Large leaf tobacco. Port Foochow.
2043. " " " Newchwang.

GUELDERLAND.

2044-2047. Leaf tobacco for wrappers.
2048. Tobacco.
2049. " for snuff.
2050. " for cigar wrappers.

BRAZIL.

2051. Tobacco.

GUELDERLAND.

2052–2063. Tobacco.

BRAZIL.

2064. Tobacco from the Colony of St. Maria.

GUELDERLAND.

2065. Tobacco for wrappers.
2066. " " "

BRAZIL.

2067–2069. Stalks of rice and rye.

CLASS 23. MISCELLANEOUS SEEDS AND PLANTS.

A. *Fibrous Plants.*

RUSSIA.

2070. Fibrous barks.
2071. " "
2072. Bast string for making rope.

BRAZIL.

2073. Fibrous plants.
2074. " barks for making rope.
2075. " " as used for rope.
2076. Rope samples.
2077. Broom made from fibrous plants.
2078. Fibrous plants.
2079–2082. Barks from trees as used for paper stock.
2083–2084. Colored fibres as used for coarse cloth.
2084*a*–2084*h*. Certain Brazilian fibres.

TURKEY.

2085. Samoa Soie.

CHINA.

2087. Coarse fibrous barks.
2088. Fibrous grass. Newchwang.
2089. " " Takow.
2090. " " "
2091. " "
2092. " " Tamsui.
2093. Fibrous plants for making ropes.
2094. Coarse hemp. King Ma.
2095. Fibrous plants for making rope.
2096. " " " " Amoy.

MEXICO.

2097. Fibres of the Agave Sisalina.
2098. " " " "
2099. Sisal hemp, Agave Sisalina.
2100. Fibres of the Maguey Agave.
2101. " Lechuguella Agave.

CHINA.

2102–2103. Fibrous grass for making cloth. Canton.
2104. Majagua.

MEXICO.

2105. Pita fibres of a bromaceous plant.
2106. Fibres of the Maguey Agave Mexicana.
2107. Pita de Lechuguella.

QUEENSLAND.

2108. Sida Ratusa.
2109. Fibres.
2110. "

HAWAIIAN ISLANDS.

2111. Fibrous barks.

RUSSIA AND HOLLAND.

2114. Flax, blue Dutch, hand scutched.
2115. " " " " "
2116. Flax, 1st qual.
2117. " 5th "
2119. "
2120. Tow No. 2.
2121. Flax, blue blossom seed, mill scutched.
2122. " Blue Dutch, Guelderland.
2123. " " " "
2124. " " " Kin of Riga seed.
2125. " " " Grown in Groningen.
2126. " " " hand scutched.
2127. " " " Friesland Prov.
2128. " " " hand scutched.
2129. " " " mill "
2130. " " " white blossom seed Friesland.
2131. Flax, blue blossom seed, mill scutched.

2132–2145. Flax.
2146. Best Friesland flax. Blue Blossom-seed.
2147–2149. Flax.
2150. Best Groningen flax. Blue Blossom, Riga.
2151. 2d qual. flax.
2152. Prime Friesland flax.
2153–2155. 2d quality B flax.
2156. 2d quality flax.
2157. Tow flax.
2158–2161. Flax.
2162–2165. Half combed flax.
2166. A. H. Whishaw & Co. flax.
2167. " " " "
2168. 1st qual. W. flax.
2169. " " flax.
2170. Best Friesland, hand scutched flax.
2171. " " " " "
2172. 1st qual. flax.
2173. 2d " "
2174. White flax, growth of 1875.
2175. " Zeeland flax.
2176. Groningen, mill scutched flax.
2177. 1st qual. flax.
2178. Best Groningen flax.
2179. " " "

TURKEY.

2180. Fibre resembling flax.
2181. " uncombed.
2182. Italian flax, unscutched.
2183. " " scutched.
2184. Fibrous barks.
2185. " "

RUSSIA.

2186. Flax unscutched.
2187. " "
2188. "
2189. Tow.
2190. Flax, 2d qual.

MEXICO.

2191. Certain fibrous barks.
2192. " " "

HAWAIIAN ISLANDS.

2193. Cloak made from grass.
2194–2220. Various fibres.

NEW YORK.

Contributed by H. W. Jones.

2221. Asbestos from Cecil C. , Md.
2222. " Mitchel Co., N. Carolina.
2223. " Felting.
2224. " paper.
2225. " as used for steam packing.
2226. " thread.
2227. " as used for cement felting.
2228. " as used for board, paper and thread.
2229. " from Harford Co., Md.
2230. " for paints, New York.
2231. " from Harford Co., Md.
2232. " used for lining felt, N. Y.
2233. " Italian.
2234. " from Richmond Co., N. Y.
2235. " " Oconee Co., S. C.

B. *Seeds and Barks.*

TURKEY.

2236. Black cherries.
2237. Hawthorn berries for hedge plants.
2238. " "

RUSSIA.

2239. Cedar nuts.

EGYPT.

2240.
2241. Capia fistulata.
2242.
2243. Cassia faliata.
2244.
2245. Goat's Thorn.
2246. red Coreopsis.
2247. yellow "
2248–2250. Dianthus sinensis.
2251. Gomphrena globosa.

BRAZIL.

2252. Marcella.
2253. "

EGYPT.

2254. Forest tree.

SWEDEN.

2255. Tall-fro, pine seed.
2256. Gran-fro.

EGYPT.

2257. Wigelia.

CHINA.

2258. Buckthorn kernels.
2259. Sesamum seed.
2260. Thorn seeds, for hedge.
2261. Seeds.

EGYPT.

2262–2266. Gourds.

TURKEY.

2267–2269. Gall nuts.

CHINA.

2270. White nuts.

TURKEY.

2271. Gall nuts.
2272. Yellow berries, for a dye.
2273. Sumac berries.

ZEELAND.

2274. Two years' dried madder root.

GUELDERLAND.

2275. Oak tan. Peeled by steam engine.

CAPE OF GOOD HOPE.

2276. Damask tree.

SPAIN.

2277. Saffron. Pruin.
2278. Alazor.

ZEELAND.

2279. Dried madder.

CAPE OF GOOD HOPE.

2280. Waggon tree.
2281. Leucandendrum No. 2.
2282. Pro-tea Mellifera.
2283. Knotted tree.
2284. Rockwood.

GUELDERLAND.

2285. Oak tan.

NETHERLANDS.

2286. Indigo seed.

CHINA.

2287. Indigo seed.

EGYPT.

2288–2291. Various seeds.

TUNIS.

2292–2294. Various seeds.

EGYPT.

2295. Seeds.
2296. Forest tree seeds.

BRAZIL.

2297. Seeds.
2298. Seeds, marked 1038.

TASMANIA.

2299. Blackwood.

EGYPT.

2300. Seeds.

NETHERLANDS.

2301. Marked No. 265.
2302. " 266.

BRAZIL.

2303. Southern moss.

EGYPT.

2304. Gauve.

MEXICO.

2305. Dye stuff.

TURKEY.

2306. Various seeds.

EGYPT.

2307–2309. Various seeds.

BRAZIL.

2310. Nuts.

CHINA.

2311–2318. Various seeds.

GUELDERLAND.

2319. Oak tree. Peeled by hand.

DEPARTMENT III. — MINING AND METALLURGY.

CLASS 25. CLAYS, KAOLIN, SILEX, EARTHS AND REFRACTORY STONES FOR FURNACE LININGS.

KENTUCKY.

2321. Pea Ridge soil. Taken 18 in. below surface.
2322. J. W. Scott. Taken 1 foot below surface.
2323. Grayson County. Taken 2 feet below surface.
2324. Little Sandy River. Taken 6 in. below surface.
2325. Iron Hill. Taken 18 in. below surface.
2326. Woods in valley of L. S. River. Taken 6 in. below surface.
2327. Virgin soil in open woods.
2328. Old field subsoil.
2329. Old field soil.
2330. Tygert's Creek. Surface soil.
2331. W. Abbot farm. Old field soil.
2332. " " " " subsoil.
2333. V. Calvin farm. Virgin soil.
2334. Iron Hill. Top soil.
2335. Surface soil.
2336. Iron Hills. Top soil.
2337. " " Subsoil 18 in. below surface.
2338. Siliceous grit.
2339. Old field subsoil.
2340. Iron Hills. 18 in. from surface.
2341. W. Abbott farm. 1 foot from surface.
2342. Iron Hills. Top soil.
2343. Grayson County. Red marl.
2344. J. W. Scott. Subsoil.
2345. " " "
2346–2401. Soils from various counties in Kentucky.

QUEENSLAND, AUSTRALIA.

2402–2405. Soil.

AFRICA.

2406–2411. Sand from the Great Desert.
2412. Sable sand.

KENTUCKY.

2413. Various samples of clay.

NEW JERSEY.

2414. Fire bricks for furnace linings, manufactured by A. Hall & Sons, New Jersey.

ENGLAND.

2415. Fire bricks, manufactured by King Brothers, Stourbridge, England.

WISCONSIN.

2416. Fire bricks from B. W. Felthousen, Milwaukee, Wis.

CLASS 26. LIMES, CEMENTS, ETC.

FRANCE.

2417. Portland cement.

RUSSIA.

2418. Riga cement.
2419. Jabe cement.

HOWE'S CAVE, N. Y.

2420–2430. Jars of powdered cement.
2431–2437. Specimens prepared for the testing machine.
2438–2441. Specimens under water two years.
2442–2456. Specimens of the crude rock from various parts of the cave.
2457. Rough stalagmite.
2458. " " broken lengthwise.
2459. Rough stalagmite broken crosswise.
2460. Polished stalagmite.
2461. Rough stalactite from the cave.

FIRE PROOF BUILDING CO., N. Y.

2462–2470. Artificial stones, manufactured for building purposes.

JOSEPH HAMBLET, STAFFORDSHIRE, ENG.

2471–2475. Artificial stones for building purposes.

ROTTERDAM, HOLLAND.

2476. Various specimens of building stones and bricks.
2477. Collections of tiles and sidewalk paving bricks.
2478. Artificial street paving stones.

CLASSES 27, 28.

A. *Ores and Associated Minerals.*

CANADA.

2479–2530. Collections of ores and minerals from various parts of the Dominion.

NEVADA AND CALIFORNIA.

2531–2536. Rich gold and silver ores.

AUSTRALIA, QUEENSLAND.

2537–2545. Native copper, lead, and tin ores.

PENNSYLVANIA.

2546–2549. Rich iron ores.

OHIO.

2550–2555. Specimens of rich native ores.

WEST VIRGINIA.

2556–2606. Specimens of ores and minerals from various parts of the State.

KENTUCKY.

2607–2631. Selected specimens from several counties.

NEW YORK.

2632. Seven specimens of Ferromanganese containing various percents of Manganese collected and furnished by H. Chapman.

2633–2640. Specimens of coal, ore, and flux, used by the Union Iron Co., Buffalo.

B. *Iron Specimens in the Pig and Rolled Bar.*

UNION IRON CO., BUFFALO, N. Y.

2641. Specimens of pig iron.

2642–2698. Specimens of rolled bars, rails and iron for building purposes.

TRENTON CO., TRENTON, N. J.

2698–2734. Specimens of rolled beams and rails.

RUSSIA.

2735. Pig iron.

2736. Specimens of rolled bar.

CLASS 29. LEAD AND SILVER.

BELGIUM.

2737–2783. Specimens of lead and silver, the products obtained by work upon a silver lead ore.

DEPARTMENT IV.—MANUFACTURES.

CLASS 30. COTTON SHEETING AND SHIRTING, PLAIN AND TWILLED.

BRAZIL.

1–16. Plain and twilled heavy cotton cloths.

AMSTERDAM, NETHERLANDS.

Samples of the Reuendoom Steam Spinning and Weaving.

17. White heavy sheeting.

18. " " " with sample of filling.

19. Bleached.

20. Unbleached.

Samples of Theversmusche Steam Spinning and Weaving.

21. Unbleached plain 42 inches wide.

22. Twilled sheeting dressed.

23. Unbleached.

Komuklykeweefcoederen Fabrik, Van C. T. Stark & Co. te Hencelo.

24–28. Cottonnets, Java.

29–45. Prentanieres Sevant.

46–52. Ginghams.

53–88. Tringano sarongs (British India).

89. Coarse heavy sheetings.

CLASS 31. COARSE FABRICS OF BARK, GRASS, ETC.

CHINA.

2784–2927. Specimens of grass cloth of various varieties.

CLASS 32. WOOLEN AND MIXED FABRICS, YARNS, ETC.

TURKEY.

2927–2929. Linen yarns and threads.
2930. Cotton thread.
2931–2933. Woolen yarns.
2934. Specimen of silk.

CLASS 33. TELEGRAPHIC WIRES AND INSULATING MATERIALS.

SIEMENS BROS., LONDON.

2935. Mediterranean cable.
2936. Military cable, braided.
2937. Harvey's Torpedo cable.
2938. Black Sea cable.
2939. Hong Kong-Shanghai-Poslette. Gt. Northern Telegr. Co. Deep Sea cable.
2940. Shore end of 2939.
2941. Platino Brazilera Telegr. Co.'s cable. Shore end.
2942–2958. Sample coils of various insulated wires.
2959–2962. Specimens of crude gutta percha used for insulating wire.
2963–2970. Specimens of gutta percha in various stages of the process of manufacture.
2971–2975. Gutta percha in the finished products.

CLASS 34. SPECIMENS OF NAILS, TACKS, ETC.

BOSTON, MASS.

2976–2982. Samples of Horse shoe nails from Globe Nail Co.
2983. Sample card of nails and tacks from the manufactory of Dunbar, Hobart & Whidden.

CLASS 35. FILES AND HARDWARE.

FRANCE.

2984–3128. Files from the manufactory of Limet Lapareille & Cie.
3129–3148. Horse shoe magnets from the same firm.

PROVIDENCE, R. I.

3149–3207. Files from the Nicholson File Co.

FROM THE WASHINGTON MILLS, ASHLAND, MASS.

3208–3243. Collection of samples of Turkish emery in the rock as found, and in the manufactured state.
3244. Cascade evaporator. Presented by Wm. R. Lafourcade.

CLASS 36. BRICKS, DRAIN TILES, ETC.

NETHERLANDS ROYAL COMMISSION.

3245. Various specimens of building and drain bricks, also samples of drain pipes.

ENGLAND.

3246–3248. Ornamental bricks for building purposes, by Joseph Hamblet, Staffordshire.

NEW JERSEY.

3249. Varieties of bricks, by A. Hall & Sons, Perth, Amboy.

CLASS 37. FIRE CLAY GOODS (CRUCIBLES, POTS, ETC.).

TAUNTON, MASS.

3250–3305. Crucibles and pots from Phœnix M'fg. Co., as follows:

1 Spelter basin.
1 No. 40, the ordinary size, steel crucible.
1 No. 50 Brass crucible.
2 No. 25 " "
2 No. 20 " "
2 No. 18 " "
2 No. 16 " "
2 No. 14 " "
2 No. 12 " "
2 No. 10 " "
2 No. 8 " "
2 No. 7 " "
2 No. 6 " "
2 No. 5 Brass crucible.
2 No. 4 " "
2 No. 3 " "
2 No. 2 " "
2 No. 1 " "
3 Jeweller's, special.

All of the sizes from No. 1 to 14 are used by jewellers for melting silver, etc.

2 No. 1 Covers.
1 No. 40 Steel cover.
2 No. 4 Dips, used by Reed & Barton.
2 No. 3 " " " U. S. Assay Office.
4 No. 2 " " " " " "
2 No. 1 " " " " " "
2 Stirrers " " " " "
2 Muzzles used by Bessemer steel works.
2 Stoppers " " " " "

CLASS 38. TILES, PLAIN AND ENCAUSTIC, ETC.

LUXEMBOURG.

3306–3312. Specimens of plain floor tiles.

NETHERLANDS.

3313. Various specimens of plain and ornamental floor tiles.
3314. Specimens of roofing tiles.
3315. " " sidewalk paving tiles.

PHILADELPHIA.

3316–3322. Enamelled and encaustic tiles, presented by Sharpless & Watts.

NEW YORK.

3323–3334. Plain and ornamental floor tiles, presented by the Fire Proof Building Co.

CLASS 39. PORCELAIN AND POTTERY.

NEW JERSEY.

3335. Various samples of earthern ware, presented by A. Hall & Sons, Perth Amboy, N. J.
3336–3337. Danish Terra Cotta.

PHILADELPHIA.

3338. Ornamental vase from British Museum, London, presented by Galloway & Graff.
3339. Vase, imitation of Danish ware, from Galloway & Graff.

CLASS 24. MINERAL COMBUSTIBLES, (COALS, ETC.).

WEST VIRGINIA.

3340–3374. Coals from various parts of the State.

PENNSYLVANIA.

3375–3380. Coals from various coal fields.

MEXICO.

3381. Rich gas coal.

AFRICA.

3382–3383. Soft coal from Orange Free State.

AUSTRALIA.

3384–3385. Queensland coal.

BRAZIL.

3386–3398. Various coals.

CANADA.

3399–3400. Pictou coal, Nova Scotia.

KENTUCKY.

3401–3418. Coals from different parts of the State.

INDIANA.

3419. Samples of various coals collected and presented by the State Commission.

ENGLAND.

3420. Pressed coal dust from Birchgrove Colliery.

SWEDEN.

3421–3425. Samples of coke and peat.

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Jasper, Gustavus A.	"
Jenks, Lewis E.	"
Kehew, John	"
Kneeland, Samuel	"

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Langley, H. P. . . "
Lanza, Gaetano . . "
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Lee, Thomas J. . . "
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Little, John M. . . "
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Parsons, Wm. . . "
Paul, J. F. . . . . "
Peabody, O. W. . . "
Perry, O. H. . . . "
Philbrick, Edward S. "
Philbrick, John D. . "
Pickering, E. C. . . "
Pickering, H. W. . "
Pope, Edward E. . "
Prang, Louis . . . "
Putnam, J. P. . . . "

Rice, Alexander H. . Boston.
Richards, R. H. . . "

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Robbins, James M. . Milton.
Robinson, J. R. . . Boston.
Rotch, Benj. S. . . "
Ruggles, John . . "
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Russell, LeBaron . Boston.

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Stevens, Benj. F. . "
Sturgis, John H. . "
Sullivan, Richard . "

Thompson, Wm. H. "
Tufts, John W. . . "
Tuxbury, Geo. W. . "

Upham, J. B. . . "
Urbino, S. R. . . . "

Ware, Chas. E. . . "
Ware, Wm. R. . . "
Warren, Cyrus M. . Brookline.
Warren, Geo. W. . Boston.
Warren, Joseph H. . "
Warren, Sam'l D. . "
Waters, C. H. . . . Clinton.
Watson, R. S. . . Milton.
Watson, Wm. . . Boston.
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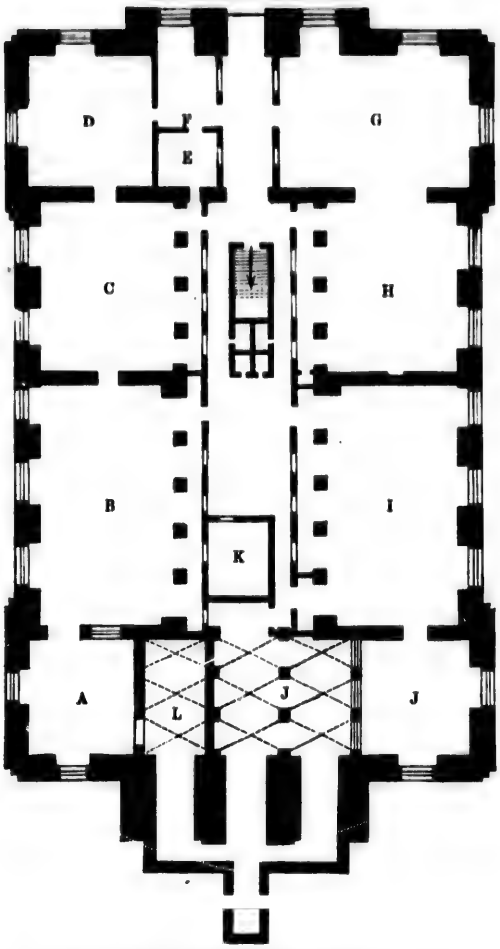
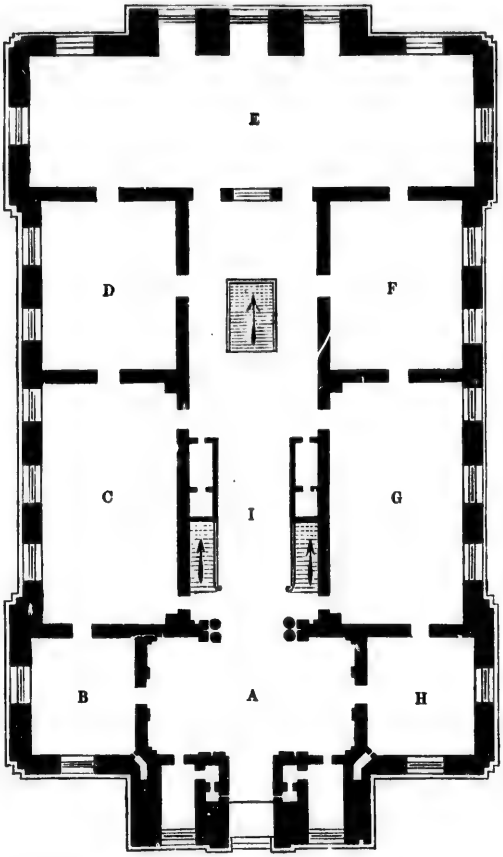
Wyman, Morrill . . Cambridge.

BASEMENT FLOOR.



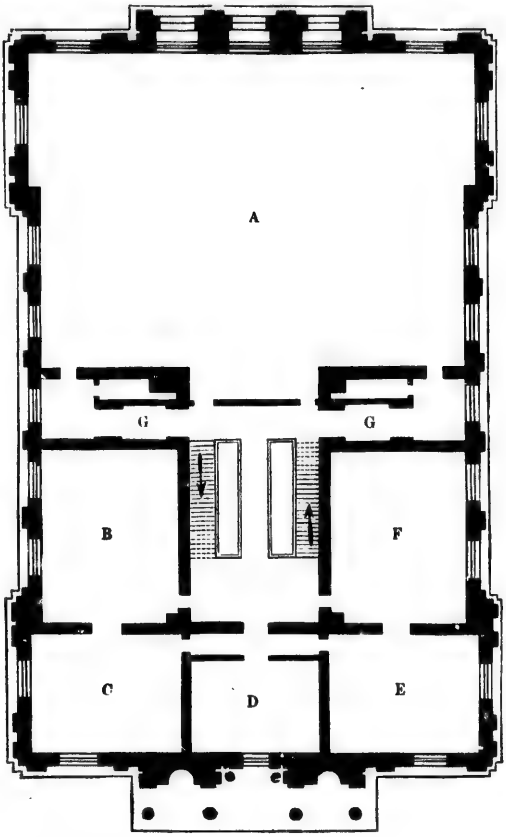
A. Professors' Chemical Laboratory, 25′ 0″ by 22′ 11″.
B. General and Qualitative Chemical Laboratory, 49′ 7″ by 34′ 0″.
C. Quantitative Chemical Laboratory, 35′ 8″ by 34′ 0″.
D. Quantitative Chemical Laboratory, 26′ 4″ by 24′ 0″.
E. Balance Room, 8′ by 13′.
F. Professor Wing's Private Laboratory, 16′ 0″ by 13′ 0″.
G. Mining Laboratory, 40′ 2″ by 27′ 10″.
H. Metallurgical Laboratory, 35′ 8″ by 34′ 0″.
I. Chemical Lecture Room, 49′ 7″ by 34′ 0″.
J. J. Mechanical Engineers' Laboratory, 25′ 0″ by 69′ 1″.
K. Daily Chemical Supply Room, 14′ 6″ by 12′ 0″.
L. Boiler Room, 15′ by 25′ 0″.

FIRST STORY FLOOR.



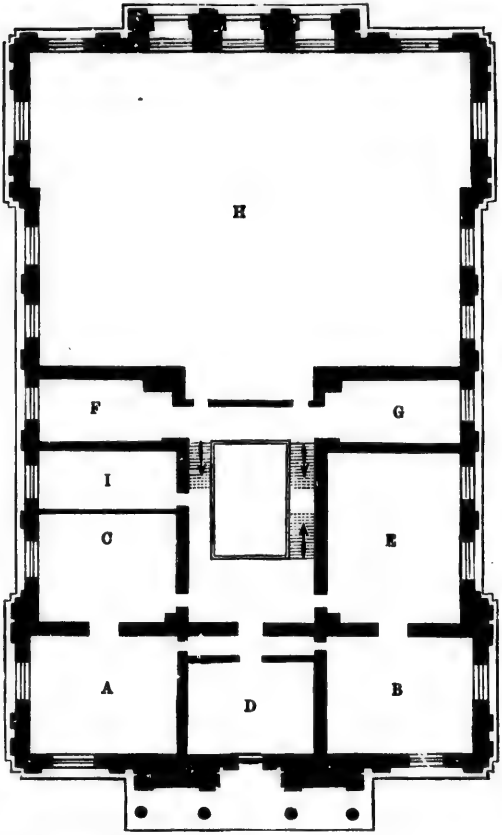
A. Entrance Hall, 42′ 2″ by 25′ 0″.
B. President's Office, 25′ 0″ by 22′ 11″.
C. Physical Lecture Room, 49′ 7″ by 28′ 3″.
D. Physical Laboratory and Apparatus Room, 35′ 8″ by 28′ 3″.
E. Physical Laboratory and Apparatus Room, 92′ 0″ by 27′ 10″.
F. Geological Lecture Room, 35′ 8″ by 28′ 3″.
G. Society of Arts Room, 49′ 7″ by 28′ 3″.
H. Secretary's Office, 25′ 0″ by 22′ 11″.
I. Stairway Hall, 87′ 3″ by 20′ 10″.

SECOND STORY FLOOR.



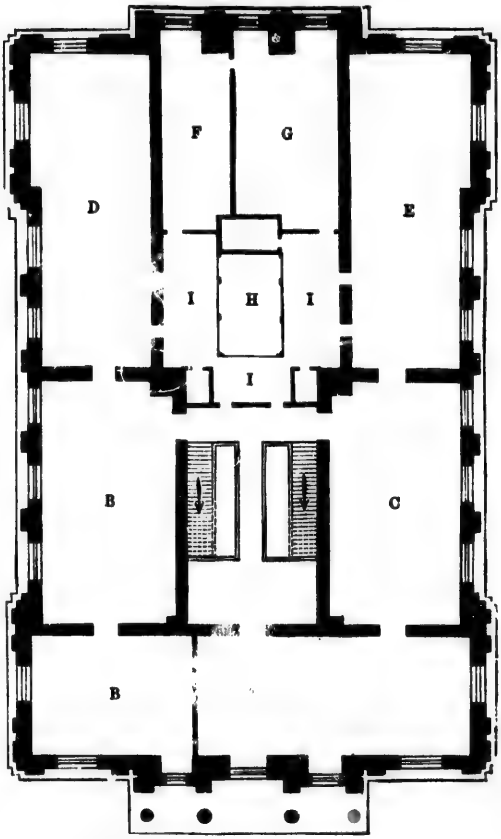
A. Huntington Hall, 92′ 0″ by 75′ 5″.
B. Mathematical Lecture Room, 34′ 9″ by 28′ 3″.
C Civil Engineering Lecture Room, 32′ 2″ by 25′ 0″.
D. Modern Language Lecture Room, 28′ 2″ by 20′ 6″.
E. English Lecture Room, 32′ 2″ by 25′ 0″.
F. Mathematical and Astronomical Lecture Room, 34′ 9″ by 28′ 3″.
G. G. Passageways to Huntington Hall.

HALF STORY FLOOR.



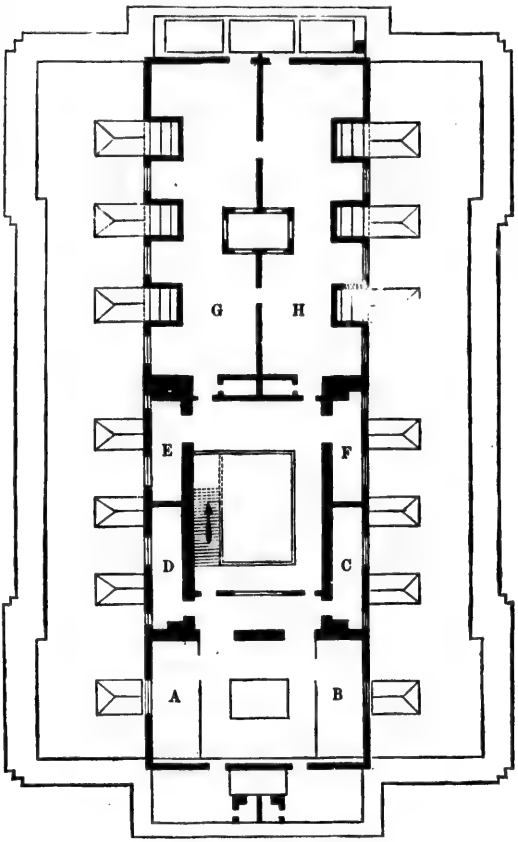
A. Architectural Museum, 32′ 2″ by 25′ 0″.
B. Architectural Library and Study Room, 32′ 2″ by 25′ 0″.
C. Architectural Museum, 28′ 3″ by 20′ 9″.
D. Natural History Lecture Room, 28′ 2″ by 20′ 6″.
E. Prof. Richards' Lecture Room, 34′ 9″ by 28′ 3″.
F. Prof. Atkinson's Study, 28′ 3″ by 14′ 2″.
G. Prof. Hunt's Study, 28′ 3″ by 14′ 2″.
H. Huntington Hall.
I. Prof. Howison's Study, 28′ 3″ by 14′.

THIRD STORY FLOOR.



A. Reading and Study Room, 62′ 0″ by 25′ 0″.
B. B. Civil Engineers' Drawing Rooms, 49′ 7″ by 28′ 3″.
C. First Year's Drawing Room, 49′ 7″ by 28′ 3″.
D. Mechanical Engineers' Drawing Room, 65′ 5″ by 26′ 0″.
E. First Year's Drawing Room, 65′ 5″ by 26′ 0″.
F. Mechanical Engineering Lecture Room, 37′ 0″ by 17′ 0″.
G. Mathematical and Descriptive Geometry Lecture Room, 37′ 0″ by 29′ 0″.
H. Model Room, 21′ 0″ by 16′ 0″.
I. I. I. Passageways.

FOURTH STORY FLOOR.



A. Prof. Lanza's and Prof. Whitaker's Study, 24′ 5″ by 11′ 6″.
B. Prof. Henck's Study, 24′ 5″ by 11′ 6″.
C. Prof. Osborne's Study, 24′ 9″ by 7′ 6″.
D. Prof. Richards's and Prof. Nichols's Study, 28′ 0″ by 7′ 6″.
E. Instructor Hoyt's Study, 21′ 6″ by 7′ 6″.
F. Prof. Ware's Study, 24′ 9″ by 7′ 6″.
G. Architects' Drawing Room, 65′ 5″ by 21′ 10″.
H. Lowell School of Design, 65′ 5″ by 21′ 10″.

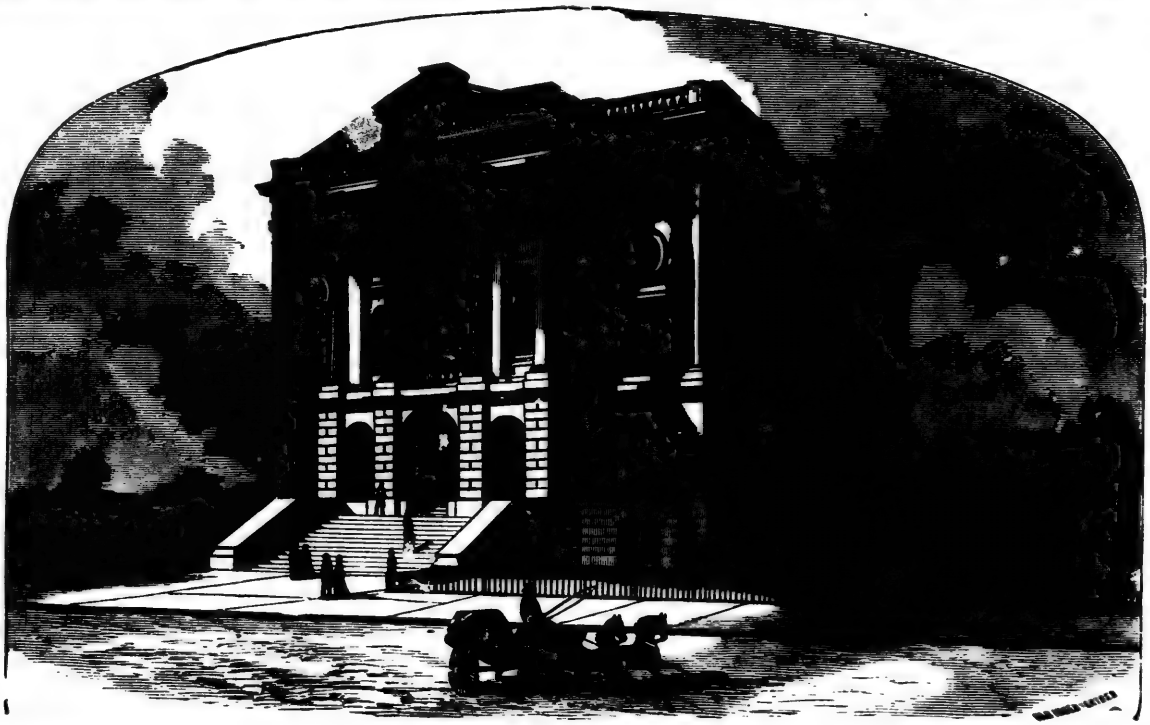
MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

PRESIDENT'S REPORT

FOR THE

Year ending Sept. 30, 1877.

BOSTON:
PRESS OF A. A. KINGMAN.
1878.



INSTITUTE BUILDING.

INSTITUTE BUILDING.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

PRESIDENT'S REPORT

FOR THE

Year ending Sept. 30, 1877.

BOSTON:
PRESS OF A. A. KINGMAN.
1878.

Extracts from Acts of the General Court of Massachusetts, in relation to the Massachusetts Institute of Technology.

Act of Incorporation. "William B. Rogers [and others named], their associates and successors, are hereby made a body corporate, by the name of the MASSACHUSETTS INSTITUTE OF TECHNOLOGY, for the purpose of instituting and maintaining a Society of Arts, a Museum of Arts, and a School of Industrial Science, and aiding generally, by suitable means, the advancement, development, and practical application of sciences in connection with arts, agriculture, manufactures, and commerce."

Chapter 183, *Acts and Resolves of* 1861.

Grant of Public Lands. "When the Massachusetts Institute of Technology shall have been duly organized, located, and established, ... there shall be appropriated and paid to its treasurer, each year, on the warrant of the Governor, for its endowment, support, and maintenance, one third part of the annual interest or income which may be received from the fund created under and by virtue of the 130th chapter of the Acts of the 37th Congress, at the second session thereof, approved July 2, 1862 [giving Public Lands to the States in aid of instruction in Agriculture, the Mechanic Arts, and Military Science and Tactics]. . . . . Said Institute of Technology, in addition to the objects set forth in its Act of Incorporation [as above quoted], shall provide for instruction in military tactics."

Chapter 186, *Acts and Resolves of* 1863.

Power to confer Degrees. "The Massachusetts Institute of Technology is hereby authorized and empowered to award and confer degrees appropriate to the several courses of study pursued in said Institution, on such conditions as are usually prescribed in universities and colleges in the United States, and according to such tests of proficiency as shall best promote the interests of sound education in this Commonwealth."

Chapter 247, *Acts and Resolves of* 1863.

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THE PRESIDENT'S REPORT.

To the Corporation of the Institute: —

I have the honor to submit my report for the year ending September 30, 1877.

The following resignations have taken place during the year:

Edward C. Pickering, S. B., Thayer Professor of Physics, and Director of the Rogers Laboratory.

William E. Hoyt, S. B., Instructor in Civil Engineering and Stereotomy.

William Foster, Assistant in the Mining and Metallurgical Laboratories.

Lewis M. Norton, Assistant in Quantitative Analysis.

Charles C. R. Fish, Assistant in General Chemistry and Qualitative Analysis.

James B. Stanwood, S. B., Assistant in Mechanical Engineering.

Clarence L. Dennett, S. B., Assistant in Mechanical Engineering.

Thomas W. Robinson, S. B., Assistant in Quantitative Analysis.

In the resignation of Professor Pickering the Institute has sustained an exceptional loss. His connection with the School, as Assistant and Professor, extended over a period of just ten years, an account of which will be found in his report for 1876. This historical sketch so plainly states the origin and growth of the laboratory method of teaching physics in the Institute, and is so full a summary of what the department has accomplished under Professor Pickering's direction, that I need only again ask your attention to it.

We are fortunate in having a Professor and Assistants who have been educated in the department, and are familiar with its spirit and methods, to continue the work.

I wish here to express, in behalf of the Corporation and Faculty, the indebtedness of the School to Professor Pickering, and to wish him every success in his new field of labor.

The following are the appointments for 1877–78.

Silas W. Holman, S. B., Assistant in Physics.

John B. Henck, Jr., S. B., Assistant in Physics.

Edward A. Handy, S. B., Assistant in Civil Engineering.

Henry M. Waitt, S. B., Assistant in Civil Engineering.

W. Bugbee Smith, A. B., Assistant in Mechanical Engineering.

Charles T. Main, S. B., Assistant in Mechanical Engineering.

Frederick A. Emmerton, S. B., Assistant in the Mining and Metallurgical Laboratories.

John Alden, S. B., Assistant in Quantitative Analysis.

Albert H. Low, S. B., Assistant in Quantitative Analysis.

John E. Hardman, S. B., Assistant in General Chemistry and Qualitative Analysis.

Henry K. Burrison, S. B., Assistant in Mechanical and Free Hand Drawing.

George F. Underwood, Assistant in Architecture.

Attendance and Graduation. The whole number in attendance during the year was 315, an increase of 16 over the previous year. For classification and other items, see page 21 of the Secretary's report. The following table shows the attendance of each year since the organization of the school, properly classified, together with the number of graduates for each year. The last two columns give the percentages of those classified as regulars during the first and second years who graduated. Many students enter the school and take the full course during the first year without intending to graduate, and others fail from various causes. The last column probably more nearly represents the true relation between those who have graduated, and those who entered with the intention of so doing.

Of 202, the whole number of graduates, 81 have graduated in the department of Civil Engineering, 34 in Mechanical Engineering, 41 in Mining Engineering, 7 in Building and Architecture, 21 in Chemistry, 1 in Metallurgy, 2 in Natural History, 4 in Physics, 9 in Science and Literature, and 2 in Philosophy.

Year.	Total.	Special students.	Regular students.				No. of graduates.	Percentage of 1st year.	Percentage of 3d year.
			1st year.	2d year.	3d year.	4th year.			
1864–65	27								
1865–66	72	9	32	31					
1866–67	137	27	64	24	22				
1867–68	167	43	56	37	14	17	14	.52	.52
1868–69	172	63	57	23	22	7	5	.16	.21
1869–70	206	54	68	45	24	15	10	.16	.27
1870–71	224	77	73	36	17	21	17	.30	.74
1871–72	264	84	91	38	33	17	11	.19	.24
1872–73	375	140	115	61	27	32	25	.37	.69
1873–74	310	128	68	59	34	21	18	.25	.47
1874–75	288	117	36	55	45	35	28	.31	.46
1875–76	2	117	66	30	43	43	42	.37	.71
1876–77		180	36	42	24	33	32	.47	.58

Abstracts of the theses by graduates of 1876–77 will be found on pp. 53–91.

There have been no radical changes during the year in any of the departments which call for an extended statement. It will be sufficient briefly to note a few points, referring to the Catalogue and past Reports for full details concerning courses of study and appliances.

In the department of Architecture there is a steady increase in the number of students who enter upon and continue the regular course to the end of the four years, and take the degree. This full course involves the theory of construction as well as of design, and it is noteworthy that in all the theses of graduates the engineering side of the problem selected for discussion is treated with care and completeness. There is a growing feeling among this class of students that any deficiencies on the

side of design can be more readily made up after graduation than on the side of construction. It is to be hoped that the time is not far distant when a large proportion of the students in this department will prefer, and be able, to take the full course.

The Steam Laboratory of the department of Mechanical Engineering has been increased by the addition of a mercury column and other appliances, and is in excellent condition. The student has now the means of practically solving all the important questions upon the nature and use of steam which arise in his course of study, or practice.

The Mining and Metallurgical Laboratories have been gradually increased in capacity and efficiency. Iron ores have at last been included in the course of practical metallurgy. The processes in ore-dressing have been made almost wholly automatic, and these laboratories are now able to handle ores in large quantities.

Besides the education of our own students, they are beginning to be used by the public for the solution of problems in which New England, through the discovery of new mining localities, has a rapidly growing interest. It is but simple justice to refer to the untiring zeal, energy and skill with which Professor Richards has developed this element of his professional work, without in the least sacrificing or lowering the scientific side of the course. He has the satisfaction of knowing that no other mining school offers its students equal practical facilities.

The Chemical department, with its increased space in the new building (see cut, page 98), is in a very satisfactory condition; but the main building would be much improved if the department had one of its own, better adapted to its wants; and it is my duty to repeat that it should not be permitted to remain in the present building any longer than can be avoided.

The Women's Laboratory has been in all respects a gratifying success, due to the high attainments of its students, and to the time and attention which Professor Ordway has devoted to it,

assisted by the zeal and able co-operation of Mrs. Professor Richards.

The Department of Military Science and Tactics, in the charge of Lieut. Hubbell, continues to be entirely satisfactory to both Faculty and students. So far as we can learn, it is only in those colleges where this instruction has been made compulsory and efficient, that it has not been a source of annoyance and demoralization.

It will be seen from Mr. Kastner's report that the students in the Lowell School of Design, through the kind aid of several loom manufacturers, have now the opportunity to learn how to weave their own designs. This will improve the chances of those who succeed, to secure desirable situations.

The new School of Mechanic Arts. It was at first supposed that the general aims of this school could be fully accomplished, and that at the same time the course of studies would be a proper preparation for those wishing to enter the higher departments of the Institute. A brief experience, however, and further consideration, soon showed that the two aims were incompatible. A large proportion of the pupils, who enter this school, have no intention of pursuing an extended course of engineering studies, but desire in the shortest time to prepare for entering upon some industrial pursuit. It has been found best to keep the wants of such students solely in view, and not attempt to provide for the few who may wish to continue their studies. Its exact relation to the advanced work of the Institute may be learned from the report of the Faculty, to be found on page 24. The only aid which this school can render to those wishing to enter the regular courses of the Institute, will be the opportunity to make up special deficiencies in studies embraced in its course of instruction.

The Mechanic Art Shops. The plan announced in my last report, of building up a series of shops in which to teach the

students in the department of Mechanical Engineering and others the use of tools, and the fundamental steps in the art of construction, in accordance with the Russian system, as exhibited at Philadelphia in 1876, has been carried steadily forward; and I have now the pleasure of announcing its near completion. The proposed shops are: —

In wood, I, Carpentry and Joinery; II, Wood Turning; III, Pattern Making: in iron, I, Vise Work; II, Forging; III, Foundery Work (moulding and casting); IV, Machine Tool Work. A full report upon the course of instruction in each of these shops will be given hereafter.

In my last report I had the pleasure of informing you that the Director of the Imperial Technical School of Moscow had been instructed by his Government to duplicate the exhibit of that school at Philadelphia, for the Institute of Technology. This very valuable gift has arrived in excellent order, of which the following is a summary. The catalogue which accompanies the collection will be printed in detail in connection with my report upon this system of instruction as carried out here, up to and including 1877–78.

SUMMARY OF CATALOGUE.

I. Collection of samples for the successive learning of wood turning. Part I. Exercise models of various channelings and other simple forms. (Ten samples.) Part II. Casting-mould models of machine details. (Thirty-six samples.)

II. Collection of samples for the successive learning of joinery and pattern making. (Thirty-six samples.)

III. Collection of patterns for iron castings. (Sixteen samples.)

IV. Samples for the successive learning of blacksmiths' manipulations. (Seventy-seven samples.)

V. Collection of samples for learning metal-turning. (Fifty-three samples.)

VI. Models of drills and countersinks to six times the ordinary size. (Fourteen samples.)

VII. Cutting parts of files increased to twenty-four times the ordinary size. (Eight samples.)

VIII. Collection of samples for the successive learning o vise work. (Forty samples.)

IX. Collection of samples of riveted joints. (Eighteen samples.)

X. Collection of samples in iron welding. (Twenty-four samples.) Each sample consists of two parts; the first represents the details of the piece prepared for welding, and the second is the welded piece.

The whole collection contains 320 pieces of exquisite workman ship, the educational value of which can hardly be overestimated.

Legation of the United States,
St. Petersburg, June 11, 1877.

Prof. J. D. RUNKLE,
Technological Institute, Boston.

SIR: — Referring to your letter of October 16th, I now have the honor to enclose you a translation of a letter received from the IV Section of His Majesty's Chancellery, which explains itself.

I have made, in behalf of your Institute, a proper acknowledgment of the kindness both of Prince Pierre d'Oldenbourg and of His Majesty the Emperor.

I am, Sir, your obedient servant,
HOFFMAN ATKINSON,
Chargé d'affaires.

St. Petersburg, 24 *May (*5 *June)* 1877.

IV Section of the Chancellery of His Majesty the Emperor.

Prince Pierre d'Oldenbourg has the honor to inform Mr. Boker, Envoy Extraordinary and Minister Plenipotentiary of the United States, that the wishes of the Technological Institute of Boston, to introduce the system of instruction in Practical Mechanics adopted by the Technical School of Moscow, was placed before the Emperor.

It has pleased His Imperial Majesty to order to be made a collection of different models at the Technical School of Moscow, and to make a present of them to the Technological Institute of Boston.

Profiting by this opportunity to tender his respects to Mr. Boker, Prince Pierre d'Oldenbourg believes that he should add, that the Honorary Curator directing the Technological School of Moscow has been informed of this supreme order to take the necessary measures for its execution.

Legation of the United States.
St. Petersburg, October 29, 1877.

JOHN D. RUNKLE, Esq.,
President Mass. Institute of Technology.

DEAR SIR: — Yesterday I received from the Moscow School of Technology eight cases of models intended for the Institute over which you preside. These cases I have shipped to you by the Wilson Line, Messrs. Sanderson & Co., agents, directly to Boston. I congratulate you on the fact that they reached me before the closing of the navigation, so that you will receive your models shortly after the arrival of this letter. . . . . .

I am, Sir, your obedient servant,
GEORGE H. BOKER.

The following, properly engrossed, has been transmitted to the Legation of the United States at St. Petersburg: —

To His Imperial Highness,
Prince PIERRE D'OLDENBOURG,
St. Petersburg, Russia.

At a meeting of the Corporation of the Massachusetts Institute of Technology, held November 20, 1877, a communication from his Excellency, Hon. George H. Boker, American Minister at St. Petersburg, was read, announcing the gift to this Institute of eight cases of models, illustrating the system of Mechanic Art education, as devised and so successfully applied at the Imperial Technical School of Moscow. The undersigned have been charged with the agreeable duty of transmitting to His Imperial Highness the following resolutions: —

Resolved, That the Corporation of the Massachusetts Institute of Technology takes this opportunity to cordially congratulate His Imperial Highness, Prince Pierre d'Oldenbourg, that, at the Imperial Technical School of Moscow, education in the Mechanic Arts has been for the first time based upon philosophical and purely educational grounds, fully justifying for it the title of the "Russian system."

Resolved, That this Corporation hereby tenders its grateful thanks to His Imperial Highness for his most valuable gift, with the assurance that these models will be of the greatest aid in promoting Mechanic Art education not only in the School of this Institute, but in all similar schools throughout the United States.

We have the honor to be
His Imperial Highness'
Obedient servants,
WILLIAM B. ROGERS,
JOHN D. RUNKLE,
SAMUEL K. LOTHROP.

The Restaurant. In the year 1874–75 the experiment of fitting up a lunch room in the gymnasium was tried, which was so successful that better accommodations were provided early in the following year.

It has been continued, and is now in a satisfactory condition. Besides our own students, and others connected with the Institute, it is patronized by students of the school connected with the Museum of Fine Arts, and some others, and this patronage aids in its support without incommoding those for whom it was especially established.

It has largely diminished the practice on the part of our students of bringing a lunch from home, and has in proportion promoted their health. It is almost impossible for a student, who lives far from Boston, and must reach the Institute by nine o'clock and remain all day, to depend upon a cold lunch, almost always taken at irregular times, to preserve his health in its full vigor. I am satisfied that this restaurant has been an important means in improving the health of many of our students; and for this reason, if no other, it should secure the interest and support of the Corporation, so far as necessary to its continued success.

In conclusion, I will say that as a whole the school has never been in a state of higher efficiency than at the present time. Our great and pressing need is additional funds; and without

immediate relief, we must either discontinue some of the departments, or cut down the salaries already too small, or more probably both. The fee for those taking the full course is $200 per annum, and it is clearly out of the question to think of increasing the income by raising the tuition. It is even now far beyond the means of many deserving students.

The value of the Institute as an agency in developing and diversifying the industries of the State can only be maintained by increasing its funds. I can not think that the large sums which have already been contributed towards the establishment of our school, and particularly the large educational facilities and experience gathered together, shall be allowed to fail of the highest results for the want of additional means.

JOHN D. RUNKLE, *President.*

SECRETARY'S REPORT FOR 1876–77.

There have been held during the year thirteen meetings of the Society of Arts.

NEW BY-LAWS.

Nov. 23, 1876. This meeting was taken up by a discussion of the best way to correct certain informalities in the preparation of new By-Laws for the Society, arising from the complicated relations existing between the Corporation and the Society. The proper committee was finally chosen, which, with the committee of the Corporation, reported a new code, which was adopted by the Society March 22, 1877, and by the Corporation April 11, 1877.

The principal differences from the old code are: that the organization and administration are much simplified, and that the funds of the Society are to be held and used for its objects, under the direction of its executive committee, with the approval of the President. It is believed that, with this simpler organization and extended powers, a greater interest will be excited in the objects of the Society, and that the number of members actively engaged in mechanical pursuits will be considerably enlarged.

The objects of the Society are to awaken and maintain an active interest in the practical sciences, and to aid generally in their advancement and development in connection with arts, agriculture, manufactures, and commerce.

The Society invites all who have any valuable knowledge of this kind, which they are willing to contribute, to attend its meetings, and become members. Persons having valuable inventions or discoveries, which they wish to explain, will find a suitable occasion in the Society meetings, under certain regulations; and while the Society will never indorse by vote or diploma, or other official recognition, any invention, discovery, theory, or machine, it will give every facility to those who wish to discuss the principles and intentions of their own machines or inventions, and will endeavor at its meetings, or through properly constituted committees, to show how far any communications made to it are likely to prove of real service to the community.

The Members may be enrolled in divisions, under the following heads, according to the taste or preference of the individual; each division to constitute a committee upon the subjects to which it appertains: —

(1.) On Mineral Materials, Mining, and the Manufacture of Iron, Copper, and other Metals.

(2.) On Organic Materials, — their Culture and Preparation.

(3.) On Tools and Implements.

(4.) On Machinery and Motive Powers.

(5.) On Textile Manufactures.

(6.) On Manufactures of Wood, Leather, Paper, India-Rubber, and Gutta-Percha.

(7.) On Pottery, Glass, Jewelry, and works in the Precious Metals.

(8.) On Chemical Products and Processes.

(9.) On Household Economy; including Warming, Illumination, Water-supply, Drainage, Ventilation, and the Preparation and Preservation of Food.

(10.) On Engineering, Architecture, and Ship-building.

(11.) On Commerce, Marine Navigation, and Inland Transportation.

(12.) On Agriculture and Rural Affairs.

(13.) On the Graphic and Fine Arts.

(14.) On Ordnance, Fire-arms, and Military Equipments.

(15.) On Physical Apparatus.

Any member may belong to more than one of the above-named Committees of Arts.

USES OF CORUNDUM.

Dec. 14. Mr. C. W. Jenks read a paper, illustrated by charts and specimens, on the uses of the mineral corundum in the arts.

Corundum, in its granular and gem forms, has been long known, having been used as an abrasive second in cutting qualities only to the diamond; and in gems, as sapphire, ruby, emerald, etc., of more value even than the diamond. The corundum emerald is specially rare and valuable, being pure alumina, much harder than the silicious emeralds. It was well known to the ancient Hebrews, Persians, and Hindoos.

Extensively used as an abrasive, and widely spread over the earth, it has not been legitimately mined until within the last five years; it has been chiefly found on the surface after rains. Every one of its varieties is extensively mined in the islands of the Ægean sea, in Asia Minor, and in an impure form in this country.

He suggested that the hieroglyphics worked upon the Egyptian monuments, of a stone so hard as to speedily blunt the hardest steel, were made by tools of corundum; at any rate, this mineral will cut the Egyptian granite and the hardest diamond. If it be true that one mine of emery is worth more to a manufacturing people than many mines of gold, this substance owing its value as an abrasive to its forty or fifty per cent. of corundum (which has a hardness of 7, the diamond being 10), what must be the value of pure corundum, which stands at 9? In the rapidly-increasing field of labor for which emery is used, the diamond is too expensive for extensive use; and this the corundum, by its pure quality and better mode of application, will accomplish cheaply and well in the case of granite, steel, the harder alloys for gun-metal, rolls for paper-making machinery, and finishing steel surfaces.

He exhibited a new sapphire wheel of nearly pure corundum. This works wet or dry, heat and acids having no effect upon it; it brings a steel tool rapidly to a cutting edge without heat or

loss of temper, as it cuts so rapidly that the slight friction has no time to develop heat. In this way it does 30 per cent. more work than the best emery, much work that emery can not do at all, and much now done by the diamond.

The corundum gems, all with the prefix of "oriental," are the sapphire, ruby, asteria, emerald, topaz, amethyst, girasol, chatoyant, and white sapphire (the last often used for the diamond). All of these have been found, of more or less purity, among the Blue Ridge mountains of western North Carolina. Both forms, the massive and the gems, are found there in the same mountain, showing that the mineralogical and geological conditions of the two are not unlike, as was supposed from their occurrence in different localities in the old world. There corundum is found in the beds of streams, or in or near their banks, as water-worn pebbles, in a secondary formation of a clayey conglomerate. It is found here also in a native matrix of ripidolite, between hanging and foot walls of serpentine, apparently undisturbed, and yet with all the appearance of water action. He had never seen any specimen in this country or in Europe which he could not duplicate from the North Carolina mine. The discovery of corundum in place is a matter of great scientific interest.

The material is stamped in the usual manner, and afterward roughly or finely ground, according to the use to be made of it. It is only about 15 per cent. more expensive than emery, and apparently does a better and more extended work.

AGRICULTURE IN MASSACHUSETTS.

Dec. 28. Mr. Albert L. Murdock, of Boston, made a communication on the "Decline and Redemption of Agriculture in Massachusetts and the United States," illustrated by maps and charts, and an extensive series of grains, especially wheats, from all parts of the world.

It is a general belief and statement that the agricultural lands of Massachusetts are exhausted; this he thought was not founded on fact. It is true that 148 towns have lost, during the last

twenty years, from 2 to 61 per cent. of their population, and from 8 to 60 per cent. of their products; the people have gone to the manufacturing centres, and our manufactures have increased at the expense of our agriculture, with a consequent large decrease in the value of farms. And yet, with all this decline, there is a production, per acre cultivated, of 35 per cent. more than twenty years ago, and 20 per cent. more in money per bushel or ton is obtained from the products of the farm.

Could three-tenths, even, of these abandoned lands be cultivated, the importation of grain from other States would be stopped. When it is remembered that a million dollars is sent out of the State every week for food that we might easily produce ourselves, and that every sixth man is out of employment, the importance of the question is evident.

The redemption of our agriculture may be brought about in various ways: — by the redemption of our salt marshes by dyking; he instanced a remarkable case in this connection at Marshfield. We do not realize this decline, being deceived by the greater yield from a few acres from superior methods of cultivation; we want more acres under cultivation, and then the modern superior methods would produce all we require. He advocated the establishment by each town of a scholarship in the Agricultural College at Amherst, with the understanding that the incumbent after graduation should reside in the town, and give one afternoon each week for the information of his townspeople, for three years, or else pay back to the town half the cost of his tuition.

He also advocated the establishment of experimental stations by the State, to be cultivated in the best and most economical manner, paying special attention to the relations of the chemical constitution of grains, etc., to the characters of soils, developing thus the best methods of cultivation and the value of fertilizers. Increased production and the employment of idle hands would then be united for the material advantage of the State.

Mr. C. L. Flint, while admitting the general accuracy and importance of Mr. Murdock's remarks, stated that farming was still profitable in the State, not in the production of the cereal grains, but in raising the vegetables and small fruits which find a ready and remunerative sale in the numerous manufacturing centres which have sprung up all over the State, crowding out the old farm agriculture. It is only labor diverted into other and perhaps more profitable channels.

INDUSTRIAL EDUCATION.

Jan. 11, 1877. A paper by Rev. Dr. Bartol was read on the "Social and Political Economy of Universal Industrial Education." Industrial education is economy of health; exercise, motion of body and soul together, is a law which is punished by debility and disease, when broken. Industrial education would make the whole people honest, open generous livelihood to all, turn the State into a bee-hive of industry, relieve the charitable societies, depopulate the prisons, abolish poverty and the alcoholic desire, and substitute the enjoyment of music and the fine art gallery for the haunts of vice. It would detect and render available the mechanical and artistic genius, which is now often lost to the world, or accidentally discovered. Labor has been considered an equivalent of drudgery and degradation too long; industrial education would convert it into interest, dignity, honor.

THE RUSSIAN SYSTEM.

President Runkle then explained the Russian system of Shop-work education, as far as it had been adopted by the Institute. The object is to educate the *hand* as well as the *mind*, without which no system of technical education is complete. The difference between *in*-struction shops and *con*-struction shops must be borne in mind, as most of the adverse criticisms of the system have arisen from ignorance or misapprehension of this vital point. The hand is instructed by the use of tools just as the mind is disciplined by mathematics, chemistry, etc., for develop-

ment, for *education*, without reference to the money value of the immediate products. The purpose here is to instruct as an *art*, and not to establish *manufacturing* shops and teach *trades*. The skillful hand can afterward readily adapt itself to any manufacture.

The *con*-struction part of the great Russian schools is not to be introduced here, and the *in*-struction shops are modified to suit American needs. Though the work done be more quickly and cheaply and better done by machinery, and even though Russian shops are fitted with American-made tools, the system may properly be called Russian, as it embraces the central idea of *class* instruction of the *hand*. It makes no difference whether the forms selected can be made by machinery or not, or whether they are of any money value; the question is, whether the making of these forms is well calculated to give the pupil the skill in the use of his hands which will be a great advantage to him whether he is to make use of it in after life as a mechanic, or whether he never touches a tool again. The time spent in this teaching is so small compared to that devoted to other studies, that the pupil has all the advantages of the regular school courses, plus the manual skill which he can use, or not, as circumstances require.

Prof. Whitaker stated that the instruction in the use of the file — an instrument acknowledged by experts as one of the most difficult to use as well as one of the most important of tools — even on useless forms, would give a manual skill to these lads which was of marketable value. He exhibited specimens of work made at the Rotterdam school, showing that as an educational system this and other *con*-struction shops were of no value, and never could be; these specimens, exhibited at Philadelphia, showed a deficiency in design and detail, of money value perhaps, but useless to make a skillful workman. In his judgment, from experience in the workshops, the two years' course at the Institute, of which the filing occupied a very small portion, would save five years of apprenticeship, and make a better workman.

Mr. H. P. Langley, a mechanic of thirty-five years' experience, expressed his surprise at the excellence of the work done in so short a time, and said that he believed it would be hard to find a mechanic who, after two years' work in the machine shops, could make such accurate fitting with the file as these lads have made after a week's instruction.

Prof. Whitaker explained that the skill so rapidly acquired was due to *class* instruction by a skillful mechanic, who taught how to do the work and how not to do it; they are not left to blunder into the right way, or to pick up the necessary knowledge accidentally, or by observation of their fellow workmen; no time is lost in making mistakes, and the pupils *start* from the standpoint of an expert's knowledge and skill.

TRADE SCHOOLS.

Mr. Newell read portions of the report on Mr. S. P. Ruggles's plan, as presented to the Social Science Association. This plan proposes to take boys at the proper age, as after passing through the grammar schools, introduce them into a developing school, and then teach such of them as show an aptitude therefor the various trades. This plan, however excellent it may be, has nothing antagonistic to the Institute system, and does not pretend to effect the same educational purpose.

COMBUSTION.

Jan. 25. Mr. H. P. Langley read a paper, illustrated by diagrams, on "Combustion and the Economical Production of Steam, with results of experiments on natural and artificial draughts, and methods of preventing smoke."

The necessity for the introduction of a considerable amount of air through the grate bars, and also into the combustion chamber of a furnace, for the complete utilization of the coal gases, seems to have received too little attention in the ordinary setting of boilers. He exhibited drawings, from the work of C. Wye Williams, of various devices for the introduction of air, mostly through perforations in the bridge walls, preventing

smoke, increasing the energy of combustion, and economizing fuel. According to this author, it makes no difference in what part of the furnace or flues this air is introduced, provided that the mixture of air and gases be continuously effected, before the temperature is reduced below that of ignition, not less than 800° Fahr.

He believed that the use of *heated* air was a fallacy, unsupported either by theory or practice; by heating the air we increase its volume, but diminish the weight of oxygen in each cubic foot, and so lessen its efficacy. The use of hot air in the blast iron furnace involves quite different principles. On the contrary, combustion may be increased by condensing the air supplied to a furnace. Of course, judgment must be used to avoid the indiscriminate supply of cold air at every stage of combustion; to secure uniformity in this respect, a mechanical is better than an artificial draught.

FUELS.

The following general rules he considers as established in regard to fuels: 1. Where a strong fire is necessary, with a large and regular supply of steam for heavy work, anthracite is without doubt the best; when boilers are large and firemen numerous, this may be changed for hard coal dust mixed with soft coal, with the use of a blower; — 2. Where the amount of steam required varies much, with corresponding heavy and light fires, Cumberland, or some soft coal would be better, with a sufficient supply of air; — 3. Dust coal has the advantage of lower price, but ten per cent. more is required to do a given amount of work, more labor is necessary to feed the fires, and generally a fan or blower must be used to get the due proportion of air; when used, the fire should be very thin, three or four inches deep, the supply being put on often and in small quantities.

NATURAL AND ARTIFICIAL DRAUGHTS.

According to Peclet, one fourth of the combustible used is expended in producing the natural draught; if this heat can be

used for making steam, and a mechanical draught will cost less, the latter is to be preferred. According to Prideaux, one pound of coal expended through mechanical agency, is capable of producing a stronger current of air than five hundred pounds expended in heating a column of air to act by a chimney thirty-five feet high; on this principle, the expense of tall chimneys may be dispensed with, and complete and smokeless combustion effected in a very simple manner.

COVERING OF PIPES AND BOILER.

At a foundry in South Boston a trial for twelve weeks was made with Pictou coal, with boiler and pipes uncovered, and covered with felt; the result was 6010 pounds of coal in favor of the felt covering. He described the "Hinkley" boiler, in which the fire is entirely surrounded by water, so that no heat can escape by radiation; in a trial of nine days with hard coal, with steam at 60 lbs., 13.94 lbs. of water were evaporated per pound of coal; with Cumberland coal, in five days, with same pressure, 13.76 lbs. of water were evaporated per pound of coal. He also explained figures of the Bonta furnace, and the Jarvis, Smith, and Walker settings.

BRIDGE WALLS.

Prof. Whitaker mentioned that an engineer of this city, having used for six months a bridge wall under his boilers, beginning at nine inches distance and going up to six, at great cost of coal, had been able to make a daily saving of two hundred and fifty pounds of the hardest Lehigh coal, by raising the bridge wall up to within five inches of the boiler, or four inches with the coating of ashes on it. He believed that the bridge wall should be within four to six inches of the boiler, and with a similar curve.

Mr. Birch advocated the use of an automatic steam damper for regulating the supply of air, claiming to have evaporated fourteen pounds of water per pound of coal, and to have saved thirty tons of coal per month by the proper mechanical introduction of air.

This subject was continued at the meeting of March 8th — see bottom of page.

DIGNITY AND NECESSITY OF LABOR.

Feb. 8 and 22. Mr. Horace McMurtrie read a paper "Labor in its relations to the human organization," and on "its Dignity, Happiness, and Pleasures."

He showed that in the very structure of the human body we find proofs that labor is a blessing and not a curse; active exercise is necessary for the development of the muscles; children at play in this way exercise their muscles more than does the hardest working laborer, and this play is necessary and natural for the development of all young animals. The functions of digestion, circulation, and respiration, require active exercise for their perfect performance. Mental labor is also necessary for the development of the brain, but unfortunately has been separated from bodily labor, as of a higher grade; man endeavors to secure happiness without labor, upon the labor of others, and is prone to look with contempt upon the very means whereby he lives. The harmonious and vigorous action of all our organs is accompanied by pleasure, and any disturbance of this harmony by pain and disease.

AUTOMATIC REGISTER.

Mr. N. M. Lowe exhibited an automatic register for mechanical motions, invented by himself. The registering is effected by the action of two levers upon a train of wheels so weighted that an index will be moved by vibration, or by eccentric or concentric motions. As it may be sealed up in any movable piece of machinery, it can not be tampered with, and is therefore reliable.

COMBUSTION.

March 8. Mr. Charles W. Birch read a paper on combustion of coal, as effected by a boiler furnace of his invention, in which what he regards as warm air is introduced by a swinging per-

forated plate over an air chamber behind the bridge wall. He had previously tried, without success, a perforated plate hung at the back of a small door cut through the bridge wall from the ash pit to the air chamber, the door being kept open.

The perforated plate is placed at an angle of about thirty degrees, sloping toward the combustion chamber, the highest edge of the plate about four inches below the centre of the bridge wall; the plate set over a chamber fourteen inches long and as wide as the boilers (four feet), the sides of the chamber sloping toward a door, twelve inches square, opening into the ash pit. The air passes through the ash pit, being thus slightly warmed, then through the door into the conical chamber, and is further heated there; thence through the perforated plate to ignite the gases under the boilers.

The following were the savings of coal in the months of 1876 over the corresponding ones in 1875, when the boilers were set on the old plan: in July, 16,300 lbs.; in August, 13,000 lbs.; in September, 17,960 lbs.; in October, 12,100 lbs.; in November, 33,540 lbs.; in December, 43,790 lbs.; or a total saving, in the six months, of 136.690 lbs. The boilers were four feet in diameter, tubes fourteen feet long and of size of three inches, and forty-nine in each boiler; floor of combustion chamber on a level with that of the ash pit; bridge walls twenty-six inches thick, and built on a seven foot sweep; distance from top of centre of bridge wall to bottom of boiler five inches. He claims that with this setting he has been able to save ten per cent. of fuel, and to furnish steam for one-eighth more work. It can be easily put under most horizontal boilers, without disturbing the setting or the piping.

Mr. McMurtrie remarked that, in his opinion, the distance between the grate bars and the bottom of the boiler was, as a rule, too small; and that the cubical contents of the furnace ought to be considered quite as much as, if not more than height of bridge walls, introduction of air, etc. From above fourteen to forty inches, and the last the best, he thinks should be the distance from the grate bars to the bottom of the boiler.

Mr Langley said that, in his judgment, the best distance was, for bituminous coal thirty inches, for anthracite twenty-four inches, and for a moderate combustion twenty inches.

SELF-TESTING GAUGE.

Mr. B. B. Keyes explained, by the instrument and by drawings on the board, his self-testing gauge for steam and other pressures.

Since steam came into general use, an instrument for indicating its varying pressure has engaged the minds of inventors. Piston gauges were first introduced, but these soon gave place to the diaphragm in various forms; then Bourdon accidentally discovered that an oval-shaped tube, bent in the form of a curve, would, when pressure was exerted on the interior, tend to straighten; from this arose the spring gauge which bears his name, familiar to all engineers.

To obviate the defects arising from unavoidable accidents which render this gauge sometimes unreliable, Mr. Keyes has devised a simple attachment whereby any hollow spring gauge may be made self-testing; he utilizes not only the horizontal but the perpendicular motions of the springs, uniting them by proper mechanism, so that these motions are transmitted to the pointers; this permitted and required firmer or stiffer springs for measuring like quantities of steam than any before used, and by no pressure, within the amount indicated on the dial, can their elasticity be affected. This device prevents vibration of the pointer under action; and the springs, being held to their lowest points, and not extending beyond a line perpendicular to this point, allow no water to remain in them, subjecting them to the danger of freezing.

STEAM REGULATING VALVE.

March 22. Mr. Joseph E. Watts, of Lawrence, exhibited a steam-regulating valve, of his invention, which had been successfully tried in several manufacturing establishments during

the past year, and upon the steam-tables in the Chemical Laboratory of the Institute.

HOUSEHOLD SANITARY SCIENCE.

April 12. Mr. H. P. Langley read a paper on "Household Sanitary Science," dwelling particularly on the impurities of air, and the necessity for a certain amount of moisture in it. He described a simple device for ventilation by the windows, and exhibited several hygrodeiks.

PROPER MOISTURE OF THE AIR.

Mr. Chester B. Merrill then made a communication on the condition of air in rooms heated by steam, and explained his invention for regulating the moisture in the same. It is found by actual tests that the temperature in such rooms is kept much too high, ranging from 70° to 80°, and that the hygrometer shows only from twenty to thirty per cent. of moisture, while it should indicate sixty per cent. When steam was introduced for heating purposes, it was said that the air would be too damp; the reverse is the fact.

At zero a cubic foot of air will hold 1.8 grains of watery vapor, at 32° 2.35, at 50° 4.24, at 100° 19.12 grains. The heating of air does not dry it in the sense of taking moisture out of it; it only renders it capable of holding more, and it drinks up moisture from everything that it comes in contact with, whether our furniture or our bodies.

He exhibited in operation a steam air-moistener, invented by himself, by which he claims that the dryness of the air in our houses, one of the principal objections to heating by steam, is overcome — the humidity of the air being regulated in this way, and shown by the hygrometer as accurately as is the temperature by the thermometer.

From remarks made by various persons, it appeared that sixty per cent. of moisture was obtained with great difficulty, and would be accompanied in very cold weather with the double disadvantage of ice on the windows and cold surfaces,

and its subsequent melting and injury to dwellings. Fifty per cent. seems to be the best degree of saturation, and air of this moisture need not be so warm as is generally considered necessary in our hot and dry rooms; double windows, with a space between them of a foot, are necessary for this purpose in cold weather.

CO-ORDINATE SURVEYING.

April 26. Mr. Henry F. Walling read a paper, the object of which was to point out a simple method in which the high degree of precision of the "Coast Survey" work may be made available in the ordinary operations of surveyors where the Coast-Survey triangulations have been carried, and to call attention to the importance of these triangulations over the entire country.

In land conveyances permanent landmarks, position of boundary lines relative to each other, and accurate statements of dimensions are generally omitted; fences, walls, hedges, ditches, streams, shore lines, boundary stones, etc., do not remain unchanged; the compass is liable to great uncertainty from the irregular action of the magnetic force and local disturbances; the theodolite and surveyor's transit afford no greater precision in retracing obliterated boundaries unless one or more well-defined lines remain for reference; the solar compass is more accurate, but its use is limited to bright or slightly cloudy days; the direct measurement of distances by the usual rod, tape or chain, is attended with even more difficulties than the measurement of directions. In a trigonometrical survey, or the measurement of angles, on the contrary, the accuracy is such that the error is reduced to a little less than two feet in one hundred miles, which would not vitiate any measurements even in the most valuable localities.

Instead of defining the position of a point by its terrestrial latitude and longitude, he would give its "latitude and departure," or its co-ordinates, from the zero point or origin of co-ordinates for the containing areas. The advantages of this

method are, he claims: 1. The highest practicable degree of accuracy, in small or large operations; 2. Great simplicity of notation, with ease and convenience of field work and computation; 3. Facility in graphic representation; 4. Absolute certainty of locations in descriptions for conveyances, and consequent removal of a fruitful cause of litigation and dispute.

Buyers and sellers of land, lawyers and conveyancers, are familiar with the defects of the prevalent modes of surveying; scarcely one deed in a hundred contains such a description of the land as would fix its location with certainty, if its fences, walls, or other boundary lines, should be obliterated; a large part of the litigation of the country arises from the imperfect surveys, or no surveys at all, upon which such conveyances are based.

CHASE GOVERNOR.

Mr. L. E. Chase exhibited his new form of governor, prefacing his explanation by a statement of the defects of all the common forms of this instrument.

The two great enemies against which the inventor has to contend here, are friction and lost motion; since, in proportion as these are overcome, will the governor valve coincide, in time and amount, with the variations of speed in the engine. All systems of jointed arms, levers, swivels, valve stems, etc., are fatal to the required conditions, since any train of the above must engender friction and lost motion, whether the governor be centrifugal, pneumatic or hydraulic. The governer valve must be as delicate and accurate as the best spring balance, and must act with the utmost nicety through minute distances.

To remedy these difficulties, this governor is made without balls, fans, paddle wheels, jointed arms or valve stems; the valves are hung upon a spring made to revolve, and are actuated directly by the centrifugal force, without the intervention of supplementary parts; friction is thus reduced to a minimum, and lost motion is entirely avoided. He exhibited it in section and by diagrams, which would be necessary for a complete

understanding of its merits. Beside its great simplicity, the following advantages are claimed for it: no revolving balls, throwing of oil, nor gears to strip or wear out; readiness of application, as it need not be taken apart, will run in any position, or either way, and can be attached to any form of engine; perfect governing power, great uniformity of speed, and complete control over the steam pressure, whether high or low; economy, as it allows no waste of steam; durability and ease of repair.

HYDRAULIC ELEVATOR.

Mr. Joseph H. Lewis exhibited in operation a model of a new hydraulic elevator for dwellings and stores. It was noted as easy of operation, economical of water, and easily adapted for variation in load, when running up or down. It differed somewhat from those in common use.

IMPROVED ORRERY.

May 10. Mr. N. M. Lowe explained a new form of orrery, of his invention. It was very ingeniously contrived to show, in a single instrument, what otherwise has hitherto required complicated and expensive apparatus. It exhibited the orbital motions of the planets in their respective planes; the seasons, months, signs of the zodiac, solstices, and equinoxes; the inclination of the earth's axis; the motions of Jupiter; the direction of the sun's rays on the earth; the places of rising and setting, and the apparent path of the sun in the heavens at the different seasons of the year; the phenomena of the midnight sun; and many other astronomical phenomena, which it is important to exhibit in schools.

MERRIMAC LEAD MINE.

This mine was discovered in 1874, when a pit was dug, and four tons of very fine smelting lead ore were taken out; the vein was found in November 1874; the ore has hitherto been shipped to New York.

Last January a lot of the poorest ore was sent to the Institute Laboratory for the experimental work of the mining students; from their experiments the value of the lead, silver, and gold per ton was carefully estimated. This was done for the double purpose of giving the students practical experience in handling work, and of trying to find a process whereby low grade ores at Newburyport could be treated with profit.

MAGNETIC MOTOR.

Mr. W. W. Gary exhibited in operation a new magnetic motor of his invention, utilizing the power of permanent magnets. He claims to have demonstrated: 1, that the polarity of an iron bar, when magnetized by induction from permanent magnets, is changed by increasing or diminishing the distance between the iron and the magnets: 2, that, according to this law, one small cell of battery may be made to operate an engine of sufficient power for sewing machines or dental engines, by using in combination with an electro-magnet powerful permanent magnets: 3, that the power of the engine is increased by the addition of permanent magnets, without additional battery power or consumption of material.

ELECTRIC CLOCK.

Mr. Thomas Hall exhibited what its inventor, Mr. Clark, of Kentucky, calls the "Perpetual Electric Clock," from its running a year and a half or two years without changing the battery or touching the clock.

In the ordinary electric clock, the swinging of the pendulum of another clock makes and breaks the circuit which sends the hands forward. In this, the weight or mainspring of the common clock is replaced by the electro-magnets; by a simple modification the hair-spring and the magnets effect the reciprocating movement, the circuit being made and broken while the wheel is travelling in the same direction. The clock, once accurately adjusted, will go without variation for about two

years, the weakening of the spring and the deterioration of the battery being about equivalent. A battery, costing about two dollars, may be placed in a closet or in the cellar, and will suffice for a clock in every room in a house, without any attention.

COPYING DESIGNS.

May 24. Mr. Thomas Hall exhibited his apparatus for copying and enlarging designs, opaque or in colors, illustrated by the lantern; the apparatus may be placed in any room ten feet high.

He compared the old, tedious, and expensive process with his rapid, cheap, and accurate method. Now the camera is used for enlarging the design on zinc or paper for the pentagraph machines, and it has many advantages over the old methods. In the old process it was necessary to make a fine outline tracing in black, on transparent paper, of all the shapes and colors in the design; this tracing was put in a camera, and the light taken from above the tracing, casting a shadow on the paper or zinc below. It took from half an hour to a week, or more, to get one of these tracings prepared for the camera, according to the size and amount of work to be traced.

In the new process, the design itself is put in the camera, and an enlarged shadow of the design is obtained on the paper or zinc in the colors in which it is painted, thereby getting a much better shadow to trace, the colors being just as they are drawn, instead of the mere outline of the colors as in the old way. By the new process are saved all the valuable time and labor necessary to make a transparent tracing, often a very important item. He had saved on one pattern some thirty to sixty dollars, and this is a specimen of what is done every day.

The advantages claimed for the new process, then, are: First — It saves much time on every pattern, thus enabling one man to do the work of two. Second — It saves the wages paid to a sketch-maker, while making transparent tracings. Third — The work is more correct, being taken from the de-

sign. Fourth — The shadow is better and more convenient to work from, as the workman can see at once just what colors he is tracing.

IMPROVEMENTS IN TELEPHONY.

Prof. A. Graham Bell gave a brief sketch of the history of telephony, and of the various ways in which he had simplified the apparatus employed. He described the original instruments, in which a battery current was used, in one of three varieties, which he called a year ago intermittent, pulsatory, and undulatory currents, characterized respectively by the alternate presence and absence of electricity upon the circuit, sudden changes in the intensity of a continuous current, and gradual changes of intensity like those in the density of air occasioned by simple vibrations. His receiving instrument then resembled a human ear, in connection with electro magnets and coils, each terminal apparatus being different from the receiving. He had ascertained that it was simply necessary to have a permanent magnet, with a simple coil with magnetized iron core, without a battery. The larger the plate the better the sound seemed to be; he had tried every size and thickness, from that of the thumb-nail to a sheet of iron four feet square, and from the thinness of tissue paper to boiler plate a quarter of an inch thick, with nearly the same results; gold-beater's skin and similar membranes in imitation of the drum of the ear were entirely unnecessary. The vibration is certainly not that of a membrane, and may be called, for want of a better name, molecular. The essentials for the telephonic apparatus, as at present constructed, are a permanent magnet, a coil, and a plate in front so placed as to vibrate freely without touching; and all these parts he has varied in many ways as to size, shape, thinness, material, etc. He finds that the thinner the coil the better the results, and he has had the best effects from a plate of soft iron, four inches in diameter and one thirty-second of an inch thick.

He exhibited a new and portable telephone, having the magnet and coil in the handle; this was passed round among the audience, who were thus enabled to hear music and conversation in a far distant room in the building. He had made a serviceable instrument which he could carry in his vest pocket.

He spoke of the social and business uses to which the telephone might be put, and drew an amusing picture of its future applications, as a time and labor saving apparatus at a moderate cost and for domestic uses.

He concluded his experiments by passing a voice through the bodies of twenty persons, standing side by side on the platform and taking hold of each other's hands. This was overcoming an immense resistance, much greater than that offered by the Atlantic cable; suggesting that, if this resistance be the chief thing to overcome, telephony may yet be substituted for telegraphy across the oceans, as it soon will be across the continents.

The meetings of the Society were then suspended till the autumn.

Of Life Members, Mr. E. B. Bigelow resigned during the year, and Messrs. J. Wiley Edmands and James McGregor died.

Mr. John Newell was elected an Associate Member. Messrs. Isaac Ames, Charles E. Buckingham, J. J. Dixwell, William Munroe, and Edmund Quincy have died during the year; fourteen have resigned, and twelve have been dropped for non-payment of fees and removal from the State. There are now on the list 59 Life, and 154 Associate Members.

SCHOOL OF INDUSTRIAL SCIENCE.

The attendance at the School of Industrial Science for the year has been 315, as follows: Graduate students, 22: Regular students of 4th year, 33; of 3d, 24; of 2d, 42; of 1st, 36; — Students not Candidates for a Degree; 4th year, 11;

3d, 7; 2d, 25; 1st, 12; Architectural students, 21; Students in School of Mechanic Arts, 23; special students in Chemistry, mostly women, 25; students in Practical Design, 47, of whom 38 were women; deduct 18, who were counted twice: = 315. Of these about five-sixths were from Massachusetts, principally from Boston and its vicinity; — from other New England States, 18: viz.; from Maine and New Hampshire 7 each, from Rhode Island and Connecticut 2 each. From other States, there were from New York 8; Illinois, 7; Ohio and Iowa, 4 each; Missouri, Texas, and California, 2 each; Georgia, Minnesota, Wisconsin, Pennsylvania, and Kentucky, 1 each; Japan, 4; Canada, 2; New Brunswick, Cuba, and the Hawaiian Islands, 1 each.

In accordance with a vote of the Corporation, the laboratory for advanced instruction in Chemistry and allied subjects for women was opened at the commencement of the year, and more than twenty, principally teachers, availed themselves of its privileges, for various periods of time and in such departments as each one felt special need. This class was under the superintendence of Prof. Ordway. A vote of the Corporation also authorized the opening of such departments of the school, as the Committee on Instruction see fit, to advanced special students of either sex, or to special classes, where it can be done without interfering with the regular work of the school. In the Department of Philosophy, Prof. Howison had a class of seven ladies, who pursued a thorough and most satisfactory course, extending through the year.

The class in "Practical Mechanism" has also been most successful.

The class in "Practical Design" has been very large, and the character of the work, fully exhibited in Philadelphia last year, has not fallen off. Decoration of tiles and table ware, and work on a loom, have been added to the course, as will be described in the Report of the Instructor, on a subsequent page.

During the year the school has lost the services of Prof. Pickering, who resigned his position as Thayer Professor of Physics to accept the post of Superintendent of the Harvard Observatory at Cambridge. Prof. Zalinski, to whose energy and perseverance the present efficient condition of the Military Department is due, was ordered back to his regiment, the time of his detail to the Institute having expired.

Thirty-two professors and teachers have been connected with the school, who have been assisted, as is customary, by several advanced students in the laboratories and in field work. The fees from students have amounted to about $45.000.

LOWELL FREE COURSES.

The Lowell Free Courses for the year were as follows:

I. *General Chemistry.* Twenty-four laboratory exercises of two hours each, on Wednesday and Saturday afternoons at 2½ o'clock, by Professor Nichols, beginning Nov. 3.

II. *Qualitative Analysis.* Twenty-four laboratory exercises of two hours each, on Wednesday and Saturday afternoons at 2½ o'clock, by Professor Nichols, beginning Nov. 8.

III. *Geology.* Eighteen lectures on Tuesday and Friday evenings at 7½ o'clock, by Professor T. Sterry Hunt, beginning Tuesday, Nov. 7.

IV. *The Philosophy of Government.* Eighteen lectures, on Monday and Wednesday evenings at 7½ o'clock, by Professor Howison, beginning Monday, Nov. 6.

V. *Practical Mechanics.* Eighteen lectures, on Tuesday and Thursday evenings at 7½ o'clock, by Professor Lanza, beginning Tuesday, Nov. 7.

These were open to both sexes over eighteen years of age, and were, as usual, well attended.

The Corporation has held ten meetings during the year.

At the meeting of May 9, 1877, the President made a detailed statement in regard to the progress, condition, and purposes of the new School of Mechanic Arts, based upon the report of the Faculty in relation thereto.

The following is the Report of the Faculty on this subject, which had received the full consideration of the Committee on the School: —

THE Committee appointed by the Faculty to consider the condition of the newly constituted Department of Practical Mechanism beg to submit the following

REPORT.

The new Department of Practical Mechanism established last year, by vote of the Corporation, is of a different character from the other departments of this school, inasmuch as the standard of age and attainments exacted of applicants is lower, the studies pursued are of inferior grade, and the course of study is shorter, no degree, of course, being given at its conclusion. In conformity with this vote, and with certain agreements entered into with the Massachusetts Mechanics' Charitable Association, workshops have been built, in which a successful course of instruction in vise-work has been carried on. This instruction has been followed by the students in the Department of Mechanical Engineering as part of their regular school work, and by volunteers from other departments of the school; by special students from outside, among whom are some of our own graduates; and by a large class of younger students, attracted by the new opportunities, for whom special instruction of an elementary character in English, French, Drawing, and Mathematics has also been provided, forming, with the shop work, a two-years' course of study. This instruction has been given in the drawing-rooms and lecture-rooms of the Institute, by some of our own number. It has been suggested that this two-years' course may prove of service in fitting boys to pass the entrance examinations of the regular course.

Your Committee have accordingly considered this work under its relations, first, to the regular students in the Department of Mechanical Engineering; second, to special students in that department; thirdly, to those younger students for whom the two-years' course is designed; and, lastly, to boys proposing by-and-by to enter our professional courses.

I. So far as relates to regular students in the course of Mechanical Engineering, or to those in any other department who may take part in it, the shop-work presents no difficulty. It obviously stands

on the same footing as any other laboratory work. The workshops are in fact and in intention one of the laboratories of the Department of Mechanical Engineering, where manual skill is acquired at the same time that a practical acquaintance with the subject-matter of the science is attained, just as in the laboratories and drawing-rooms of other departments. They are solely for instruction, and are to have no manufacturing or mercantile character whatever.

The value of this work to these students, and the amount of time properly to be given to it, are matters which your Committee have not felt themselves called upon to consider. The decision of these points lies with the head of the department, acting, of course, as in any other laboratory work, with the advice and consent of the Faculty and of Committee on Instruction.

II. Special Students may, of course, be received into this laboratory, so far as convenience permits, just as into other laboratories or drawing-rooms: and the Special Students may, agreeably to the custom in other departments, take part in such other instruction as they are qualified to profit by, under such rules as may be established. Their case, also, presents no difficulty.

If the interest that has already been shown in this work is ultimately warranted by its success, we may expect a considerable number of young men to come to us to learn the methods here pursued, in order to become teachers in similar instruction-shops elsewhere. All such students, also, would be classed as Special Students in the Department of Mechanical Engineering.

III. It might seem at first as if the students who pursue the two-years' special course above described might also be classed as Special Students in this department, their work in the instruction-shops being the same as that of the Regular Students. They are younger and more ignorant; but it might be considered, and your Committee were at first disposed to consider, that the difference was one of degree, not of kind. In the Department of Architecture, a special two-years' course has been established for the somewhat miscellaneous body of young men who appear in the catalogue as Special Students in that department, and this seemed at first to furnish a precedent applicable to the case in hand; but the difference of the two cases is an essential one. The important question is the question of age. The students

in the special course in Practical Mechanism are boys, and it is for boys that that course is intended. They need the care and discipline that school-boys require. Experience shows already that the methods adapted to our own students do not meet their case. Their studies, outside their shop-work, should be conducted in separate rooms, under the constant supervision of special instructors and disciplinarians.

Moreover, although the shop-work is the characteristic, and, in a sense, the most important part of such a course, since it is the element that distinguishes it from ordinary schooling, it by no means occupies the chief part of these boys' time. The greater part of the day must be occupied, as with other boys of their age, with reading, writing, arithmetic, and drawing, with something of natural science, and perhaps some one of the modern languages. And these studies, if judiciously chosen, need not be any less practical in character than the exercises in the workshops. The arithmetic of mensuration, for instance, with the computations involved in the elementary phenomena of physics and mechanics, would enable the student of any of the mechanic arts to cover a great deal of ground in a way at once entirely practical and eminently scientific. This is the sort of training which, in the decay of the system of apprenticeship, the intelligent workman needs. It is a training that the High Schools and Academies cannot supply, and it is entirely different from anything needed by the students in our professional courses. What is wanted is something which shall come after the Grammar School, and shall put boys in the way to become master mechanics. They need a schooling, but one neither literary nor mercantile in character; a training which, though based upon the the applied sciences, shall be entirely practical in its methods, and it is something of this sort that the instruction in practical mechanism already organized undertakes to supply.

But it seems to us a matter of regret that this instruction should have been organized exactly in the shape that it now presents. As a department in our own school it holds, as has been intimated, an entirely anomalous position, resembling the other departments only in name, and, while its real importance is obscured, tending to disparage the professional courses by its presence among them. To have ranked these students as Special Students in Mechanical Engineering would have been, in terms, more consistent with the rest of our organization; but the consistency here again would have been only nominal. These

students are not really what we mean by Special Students; besides, it would not have been fair to throw upon that department the burden and responsibility of such a charge, especially if, as may well happen, this instruction should come to include other practical arts not specially related to the work of that department, and involving the fitting up of instruction-shops with which its own students would have nothing to do. We cannot but regret that the Corporation did not establish the new work at once on a more independent footing, giving it a position so distinct from the professional training previously undertaken that we should not appear to be changing our policy or lowering our standard, while the new work should clearly appear to be a new one. If the Corporation should, even now, see fit to revise their action, and, instead of establishing a new department in this school, create a separate school, of a subsidiary character, though under the management and direction of the same Faculty, it would seem to your Committee to be the best statement of what they have in fact already done.

If this view should commend itself to the Faculty, we would recommend that the President be requested to signify the same to the Corporation.

This would not necessarily involve any increase of the work beyond its present dimensions, while it would put it on a juster footing, and one more favorable to its natural development. But whatever extension may ultimately be in store for it, the character of the work done in the instruction-shops must, for some time to come, be fixed by the requirements of the several professional departments, as it is at present by those of the Department of Mechanical Engineering; and any other instruction-shop that may hereafter be added must be, as the filing-shop is now, primarily a professional laboratory.

What experience has been already gained would seem to show that such work, being absolutely new to all, is equally well adapted to all classes of students.

IV. As to the serviceableness of such studies to young men proposing afterwards to enter the Institute as Regular Students, we do not see that it can well be made to answer the general demand for such preparatory schooling. Such a school would differ too much from the High Schools and Academies from which our students come for us to expect from it the same class of students; and even the

High Schools and Academies hardly meet our demands. But special cases may constantly arise of students ready or nearly ready to enter our classes, to whom a year of practical instruction would be of great service; and this may prove the best practicable course for some of those who apply for admission to the Institute, but are not quite prepared to pass our entrance examinations. Besides, it does not seem to us desirable that the Institute should be understood to maintain a Preparatory Department.

WILLIAM R. WARE.
JOHN M. ORDWAY.
GEORGE H. HOWISON.

Boston, Feb. 21, 1877.

After considerable discussion, it was voted that this instruction be given in separate rooms — that the department be known as the "School of Mechanic Arts" — that it be not regarded as preparatory to the regular school of the Institute — and that it be under the control of the Committee on the School as are all other departments of instruction in the Institute.

DEGREES CONFERRED.

At the meeting of June 5, it was voted that the Degree of Bachelor of Science be conferred on the following students, who had fulfilled all the requirements for the Degree, and who had been recommended by the Faculty and the Committee on the School: —

Henry H. Carter . . .	Roxbury	Civil Engineering
Martin Gay	Staten Island, N. Y.	" "
Joseph P. Gray	Lowell	" "
Edmund Grover . . .	E. Walpole . . .	" "
Richard A. Hale . . .	Lawrence	" "
Geo. W. Kittredge . . .	N. Andover . . .	" "
Charles F. Lawton . .	New Bedford . . .	" "
Benj. C. Mudge . . .	Lynn	" "
Arthur L. Plimpton . .	Boston	" "
Charles E. Stewart . .	Boston	" "
Geo. F. Swain	San Francisco, Cal.	" "
Frank E. Wiggin . . .	Boston	" "

William H. Beeching . .	Boston	Mechanical	Engineer'g.
Geo. H. Chapman . . .	Winchester . . .	"	"
Linus Faunce	Kingston	"	"
Charles H. Fisher . . .	Canton	"	"
Joseph Kirk	Dorchester . . .	"	"
Cecil H. Peabody . . .	Chicago, Ill. . . .	"	"
George Bartol	Lancaster	Mining	Engineering.
William C. Flint . . .	Salem	"	"
John E. Hardman . . .	Lowell	"	"
Henry D. Hibbard . . .	W. Roxbury . . .	"	"
Walter Jenney	Boston	"	"
Harry C. Southworth .	Stoughton	"	"
Thomas F. Stimpson . .	Swampscott . . .	"	"
Fred. W. Wood . . .	Lowell	"	"
J. Williams Beal . . .	S. Scituate	Architecture.	
George W. Capen . . .	Canton	"	
Wm. E. Chamberlin . .	Cambridgeport . .	"	
Pierce P. Furber . . .	Cottage Grove, Minn.	"	
John Alden	Randolph	Chemistry.	
Charles S. Bachelder . .	Brookline	"	

The subjects of the Theses and the abstracts of the same will be found in subsequent pages.

The progress and present condition of the school in its various departments, will be stated in the reports of the President and Professors.

SAMUEL KNEELAND, *Secretary.*

Boston, Sept. 29, 1877.

DEPARTMENT OF PHILOSOPHY.

To the President: —

The programme, as now established and printed in the catalogue for the current year, has been duly carried out. The work assigned for all regulars has been accomplished by them in a satisfactory manner.

In the Department proper of philosophy, there have been no *regular* students this year; but the opening of special courses to persons of either sex, in accordance with the Government's vote of May 10, 1876, resulted in the entrance of a number of young women (seven) upon the Introductory Course in Philosophy, — that laid down for the Second-year students in the Department. Their work proved to be a signal success, and four of them will continue in the Department the coming year, to take a course upon Hume and Kant.

In June last, as the contribution of the Department to the general exhibition (then contemplated, but afterwards given up) of the Institute's School of Industrial Science, an "Account of the Department of Philosophy in the Massachusetts Institute of Technology" was printed, making a pamphlet of 72 pages. It included (I) an account of our various doings from 1872 to the date of publication, fully illustrated by specimen examination-papers, (II) the theses by the men who were graduated in 1876, and (III) the *verbatim* examination-papers produced at the last Annual by the young women mentioned above. The Government are respectfully referred to this "Account" for full details of our operations during the year just closed.

Respectfully submitted,

GEO. H. HOWISON.

DEPARTMENT OF MILITARY SCIENCE AND TACTICS.

President J. D. Runkle:—

Sir, I have the honor to submit herewith my report of the Department of Military Science and Tactics for the School year ending September 30th, 1877.

I assumed charge of the Department at the beginning of the year, and finding the status of the Military Course to have been the result of careful deliberation and experiment on the part of the Corporation, the Faculty and my predecessor Lieut. Zalinski, I instituted no changes and have none to recommend. A new element however, has been added to the School during the past year, viz.; the Department of Mechanic Arts, and I respectfully recommend that the students attending this Department be required in their first year to attend drills. I think the exercise so obtained would be of benefit to them in counteracting any injurious tendency of their confined shop work, which necessitates more or less labor while in a stooping posture.

These students, should they subsequently enter the regular first year's course, would be able to pass the required examination in tactics and so omit drill for that year, while some of them, as volunteers, would be useful as officers and non-commissioned officers. The small size of the First year class during the past year, averaging about forty for drill, made it inexpedient to form a battalion. I therefore organized the Corps as a Company, retaining, however, the offices of Adjutant and Quartermaster, the duties of which were mainly clerical. During the regular drill hours instruction was given in Infantry drill, including skirmishing, and during recreation hours, volun-

teer detachments were instructed in Artillery drill, rifle practice, and military signalling. The discipline of the Corps has been good and the officers zealous and efficient. I consider them well qualified to perform the duties of their respective grades in any volunteer organization in the country. They were as follows: —

Staff Officers ranking as First Lieutenants.

Adjutant — F. R. Loring.
Quartermaster — J. H. Tibbetts.*

Line Officers.

Captain — E. C. Miller.
First Lieutenant — W. T. Miller.
Second Lieutenants — L. R. Millen and N. B. Morton.

The Second Year Class attended lectures on Discipline, Administration, Camps, Marches, Outpost duty, Military Hygiene, and the principles of Field Fortification.

Through the liberality of a gentleman interested in Military education, I was enabled to offer a prize for the best essay on a given subject. The subject discussed was; — "In this country, with a small standing army, how best to apply the maxim, 'In time of peace, prepare for war.'" There were seven competitors, all of whom evinced thought and originality in their papers. The prize was awarded to Mr. F. B. Knapp.

I am, very respectfully, yours,

H. W. HUBBELL, JR.
1st Lieut. 1st Arty.,
U. S. A.

* Mr. Tibbetts left the Institute after the semi-annual examination. The duties of the Q. M. Dept. were faithfully performed during the remainder of the year by Q. M. Sergt. L. P. Howe.

DEPARTMENT OF ENGLISH AND HISTORY.

President Runkle : —

Sir : — I hereby present through you to the Government of the Institute of Technology, the following account of the condition and work of the department of English and History.

The Freshman Class spend two hours per week in exercises in "Rhetoric and Composition." The first object of these lessons is an elementary one; namely, to supplement the usually great deficiencies of their school education by a review of the rudiments of the subject. To this end, that part of the manuals of Rhetoric is gone over which contains the rules for the construction of sentences, the definitions of figures, and other elementary matters, and this review is accompanied by class exercises, and the requirement of a considerable amount of written composition. This, however, is but the least part in the real work needful for the formation of a good style. That object can never be accomplished through the mere learning of rules and the correction of the crude performances of beginners; but requires, as a necessary element, much and careful reading of good writers. I therefore begin as soon as possible the much-needed labor of teaching our young men *how to read*, by the critical study of selected texts, and the practical application to them of the rules and principles laid down in the Rhetorics. The recent publication in a cheap form of various series of specimens of standard writers in

rose and poetry,[1] will hereafter enable me to read with the class a varied series of complete texts without overburdening the student with the expense of costly editions of the whole works of the different authors. It also puts within our reach for critical study, typical specimens of *modern* writers.

This series of exercises seems to me to be exactly in place in the first year, and experience has proved their necessity to the great majority of the students who attend our school. In proportion to its importance, the time allowed it on our schedule is necessarily short, and it is greatly to be desired that the preliminary review of elementary rules could altogether be dispensed with. I purpose hereafter to "condition" somewhat rigorously all candidates for admission who do not show real familiarity with such practical exercises as are contained, for instance, in the first four chapters of Hart's "Rhetoric and Composition," to require the making-up of such exercises, and to begin the critical reading of texts, as well as the practice of composition immediately. Nothing is more important than to teach such students as ours how to read; for, more than all rules of Rhetoric, the habit of careful reading will lead to accurate thinking, and therefore to clear writing; while a comparison of the different styles of the real masters of composition — a comparison which, whatever may be the imperfections of their school training, our students are quite mature enough to begin — is the only method by which life can be infused into the abstractions of the rhetorical manuals, and the surest way to correct the crudities in their own attempts at composition.

A course in English Literature is assigned me with the class of the Second Year. A "course in English Literature" is usually understood to mean a course of lectures embracing a general survey of English literary history; but such a survey must, from the necessity of the case, be extremely superficial, and can hardly do more than follow in the beaten track of printed "com-

[1] The Oxford "Clarendon Press Series"; The "Vest-Pocket Series" of Osgood & Co.; Harper's "Half-Hour Series."

pendiums" and "manuals." There is, to be sure, ample room for a diligent instructor who could afford to give his whole time to the subject, to make such a course highly instructive to students of sufficient maturity of thought; but such instruction should be the completion, not the beginning, of the course in Literature, and would find its appropriate place in the last year, where, at present, there is no room for it; neither, if there were, would the multiplicity of my present duties allow me sufficient leisure for the thought and study required to do it justice. A more appropriate course for second-year students is to give a practical example of the way in which such studies should be pursued, by confining the student's attention to a limited period, combining History and Literature together, as only two sides of the same subject, and continuing the critical reading of texts begun in the first year. A step further, however, may be taken, and the laboratory method of research may be imitated, by setting the student simple problems to work out in Political History, and in Literature and Criticism, with the help of my own and the City Library. This gives room for the only practice in advanced composition which is good for anything, the writing of papers on subjects which the student has actually investigated, and in which he feels a genuine interest. By a method of study of this kind, accompanied by a carefully prepared course of lessons from the instructor, both the inner and the outer life of a limited period, that is to say, the history of thought and the history of action, may be investigated in a tolerably satisfactory manner within the assigned limits, and the true nature of historical and literary study can be pretty well illustrated. A course so managed will be very sure to give birth to an interest in such intrinsically interesting subjects, even where that interest had been previously kept in abeyance by bad school teaching. Of this I have evidence in the application of portions of classes for leave to continue such studies voluntarily with me after the regular course is over.

It seems to me extremely important to the real success of

our school, that the cultivation of such tastes should be encouraged. The question is sometimes raised by superficial thinkers who pride themselves on being "practical" in their views of education, what place has the study of Belles Lettres, and even of History, in a course of study intended to prepare young men for a practical scientific profession. I observe with satisfaction that the uniform tenor of the discussions on education among practical scientific men themselves, is in favor of enlarging rather than narrowing the general literary element in their education.[1] Their almost unanimous opinion, drawn from practical experience, seems to accord with that of all the best theorists on the subject, that it needs an enlarged and many-sided culture of the intellectual powers to make a man successful even in the speciality to which he devotes his life, and that an engineer who is nothing but an engineer, cannot be, in the highest sense, even a good engineer. An English man of business[2] has recently made a striking plea for the culture of the *imagination* as a necessary element in any good preparation for business life, and has urged, with much ingenious and forcible illustration, the importance of historical and literary studies, as forming an essential part of the education of practical men. In the necessary absence of classical study from our course of instruction, the study of the English language and of English Literature and History, becomes from this point of view doubly important. In the sharp competition for pupils, which is beginning to arise between the various scientific schools of this country, those only will gain any permanent footing, or meet the approval of that minority of competent judges in the community on whose favorable verdict the success of such institutions must sooner or later depend, which have arranged their courses of study on really sound views as to what constitutes a good scientific liberal education. And it

[1] See particularly "Discussions on Technical Education, at the meeting of the Am. Inst. of Mining Engineers and the Am. Society of Civil Engineers," Easton, Pa., 1876.

[2] Mr. Goschen, M.P., the eminent London banker. See the Liverpool Daily Courier, Nov. 30, 1877.

will not do to say that the general element in such an education can be equally well represented by any and all kinds of general study, and that, beyond his strictly professional tasks, it is quite a matter of indifference whether the future engineer exercises his mental faculties on Greek or Hebrew, or any modern study which may be the prevailing educational fashion of the moment. In my judgment, the general studies of a professional man should be selected with quite as much care as his strictly technical studies, and it is not a matter of indifference whether the mental habits they create are in harmony or in antagonism with those generated by the professional part of his curriculum. Making allowance for peculiar idiosyncracies which may occasionally give a strong individual bent in the direction of some favorite bye-study, it may be said that the general element in the education of a young man destined for an active profession, should consist of those ingredients which will supplement the narrowness of his technical training in the direction of making him first a good citizen, next a good man of business, and next in the direction of opening to him a source of pure and elevated pleasure, by arousing in him a taste for what is beautiful in Literature and Art. The first object will be gained by the teaching of history and political science, the second by exercising his mind in the examination and discussion of economic subjects, and the last by opening to him the resources of one or more foreign literatures, while his taste is cultivated to appreciate all that is excellent in what is perhaps the richest of all modern literatures, his own. This surely is enough, and more than enough, for the surplus time and mental energy left from the demands of a rigid professional training in mathematical and physical science.

And in my judgment these non-professional studies should be conducted, — indeed in the present condition of our school they *must* be conducted, — in a different spirit and with different aims from those which must govern the professional. They should not be merely hard and disciplinary. The work should be done, as all intellectual work should be done, with care and

accuracy but it should be so conducted as to be a pleasurable relief rather than an additional burthen. The aim should be to implant tastes, to create new interests in subjects to which justice can be done only in the leisure and maturity of after life. The technical studies of our young men constitute a mental drill of the severest kind; but it is the foolishest and falsest of all narrow views of education the notion that it should be all drill. I have yearly cause to lament that this truth is not better understood when I see in our entrance examination-papers in History and Literature the barren results of so much honest but misdirected school labor.

There is at present but little room and less preparation for the systematic study of the moral and political sciences of which History and Literature are but the illustration. These would draw too largely upon the time and brains of students already exhausted by the demands of their professional work; but lighter courses in History and Literature may by judicious management be made a preparation for the more systematic prosecution of such studies in the leisure and maturity of after life. For one of the historical sciences, the Science of Government, a small opportunity is given in a short course on "Constitutional History" in the third year. I think it is very much to be desired that room should also be found in the course of study of all regular students for a part at least of the instruction which — in the absence of any regular provision — I have thus far volunteered to give the students in the department of Science and Literature in Political Economy. This is another of those studies, some knowledge of which is a necessary foundation to all profitable reading of History, and it seems almost an absurdity that in a practical school like ours some attention to this, one of the most important of all practical subjects, should not be required of all students.

It is very true, as I have already said, that our professional students can spare but a very inadequate portion of their time to these general studies. That is an evil for which there is but one remedy, a better preparation for admission, and I judge, as

one of the examiners, that it is an evil which is lessening year by year, and one which will lessen very rapidly as soon as better methods of elementary scientific preparation shall penetrate our High Schools. As soon as our young men bring to us that equipment of elementary mathematical and scientific knowledge which, with good training, they should possess at the age of seventeen, there will be far better opportunity for the higher English studies after their admission; and I think that time is not far distant. Instead therefore of narrowing the scope of the historical and literary instruction given in the Institute, I respectfully urge upon the Government the necessity for more liberal provision, in anticipation of a fast-approaching time when our students can afford to devote a larger share of attention to the element of general culture. That that general element should with us largely take the form of the study of History and Literature, and more particularly of the study of English History and the English Language and Literature seems to me beyond question.

I desire again earnestly to call the attention of the Government to the unsatisfactory condition of the so-called "Science and Literature" department. While it is never without just enough students to make my position a very laborious one, it yet adds nothing to the strength or the resources of the institution. I am confident that by a reorganization it might add to both. While we are not in a position, and it will never be our proper function to attempt to cover the wide field of general education embraced by our colleges, there is one special department of education quite germane to the purposes for which our institution was founded, which is nowhere well provided for, and which we might undertake with every prospect of success. I mean the preparation of young men for active business life by an education in the study of the modern languages, the experimental study of natural and physical science, and in English subjects, including History and Literature, the elements of Law and Political Science, Political Economy and Statistics, and Commercial and Industrial Geography. There is a large and

rapidly increasing class of young men in the community who, for various reasons, are not prepared, on the one hand, to invest their chool years in the study of the ancient languages which is required for admission to our colleges, and on the other hand, have no taste or talent for engineering, or the other technical professions, but who yet do desire something beyond the education which our high schools give. By a not expensive addition to our teaching force, as at present organized, and by proper modifications in the course in "Science and Literature" — such modifications as shall give it a character as distinctly individual as the course in Chemistry, or the courses in Engineering — that course might be made to meet exactly this want. As at present arranged, it fully meets no want, and consequently attracts few students.

All which is respectfully submitted.

WM. P. ATKINSON,

Professor of English and History.

DEPARTMENT OF MODERN LANGUAGES.

President Runkle: —

Dear Sir, Permit me to present herewith the report of the department of Modern Languages for the school year 1876–77.

FRENCH REQUIREMENT FOR ADMISSION.

The following shows the result of the last examination for admission, including that of the autumn of 1877.

1877.	
52	No. of students in First Year.
58	Average mark at Entrance Examination.
0	No. admitted without French.
41	No. admitted without conditions.
65	Average mark.
11	No. admitted with conditions.
81	Average mark.

By comparing the above with the results of previous years, as given in my last report, it appears that there continues to be a gradual improvement in the manner in which the requirement is fulfilled. There was still, however, such an inequality, that it was found necessary to form, of those who were behindhand, a class which has recited oftener and apart from the rest. The number in this Elementary class was nine throughout the year. The French required for admission is now, as indicated in the Annual Catalogue: "French grammar, through regu-

lar and irregular verbs, and the first two books of Voltaire's 'Charles XII' (about seventy pages)".

From blanks filled out at the examination, it appears that of the sixty-seven candidates for the First Year, fifty-eight stated that French was a regular study in the school where they prepared, and forty-two that Latin was, while forty-four reported that they had studied Latin.

WORK OF THE PAST YEAR.

The number of exercises per week in the department were thirty the first term, and twenty-seven the second. The following shows what has been read, and the amount.

FRENCH.

FIRST YEAR. Voltaire — "Charles XII," 80 pages. Tissandier — "L'eau," 172 pages. Töpfer — "Nouvelles Génevoises," 58 pages.

THIRD YEAR (Sc. and Lit.). Brueys — "L Avocat Patelin." Molière — "Les femmes savantes," "L'Étourdi," "Le médecin malgré lui."

FOURTH YEAR (first half). Mémoires — extracts from de Retz, St. Simon. 59 pages. Molière — Le bourgeois gentilhomme," 3 acts.

GERMAN.

SECOND YEAR. Whitney's Reader, 26 pages. Selections, 20 pages. Andersen's "Märchen," 16 pages.

THIRD YEAR. Whitney's Reader, 39 pages. Pfaff — "Das Wasser," 158 pages. Putlitz — "Das Herz vergessen." Benedix — "Eigensinn."

FOURTH YEAR (Sc. and Lit.). Portions of Schiller's "Wallenstein."

Exercises in composition, written and oral, and on the forms and principles of the languages in question, have accompanied the above work in translation.

During the first term there was an optional class of eight students, that commenced the study of Spanish, using Sale's grammar, and reading twenty-five pages in Don Quijote. During the second term there was an optional class of six students, that attended a course of French readings, consisting of Victor Hugo — "Ernani," Beaumarchais — "Barbier de Séville," De Musset — "Un Caprice."

Following, are the examination papers at the Annual of the

First Year in French, and Third Year in German, with the average mark of the whole class on the same.

Respectfully submitted,
CHARLES P. OTIS.

[EXAMINATION PAPER OF THE FIRST YEAR AT THE ANNUAL.]

Number of students 27. Average mark 66.

I. Il se peut que les glaces amoncelées au pôle Nord amènent, comme le veut Agassiz, un mouvement subit dans l'axe de la terre, qui, par suite du changement de position de son centre de gravité, serait soumise à une terrible secousse, causant la mort de tout être inanimé, en déplaçant brusquement les océans. Il se peut que la terre, se refroidissant toujours par son rayonnement à travers l'espace, voie son épiderme, qui n'est en définitive qu'une croute figée par l'action du froid, augmenter d'épaisseur, et qu'un jour vienne où l'abaissement de la température soit tel, que l'eau n'existe plus sur notre sphère qu' à l'état de glace. Ajoutons toutefois que, si ces prévisions se réalisaient jamais, ce ne serait que dans une suite de siècles considérables.

1. Point out and explain the subjunctive forms in the above.

2. Explain the force of *se réalisaient*, and turn the sentence into any form it may take without a change of meaning.

3. Tell what you know about *en* in *en déplaçant*.

4. Give in full the present indic. of *peut*, the future of *voie*, the pres. subj. of *veut*, and the compound present of *se refroidissant*.

Render in French: The snow has been falling for several days, and the fields are covered with it; yet, although the cold is sharp,[1] it is not believed that the ice can bear.

[1] *perçan'*.

II. En 1816, un paysan de Silésie, nommé Priessnitz, revenait de son champ, quand un cheval emporté le renverse, imprime ses fers sur son visage et lui brise deux côtes. Il n'y avait pas de médecin dans le petit village de Freiwaldau; Priessnitz veut se guérir lui même. Il fait peu à peu reprendre à ses côtes brisées leur direction première, en s'appuyant constamment la poitrine contre l'angle d'une chaise; pour tout bandage, il se sert d'un linge mouillé; il boit abondamment de l'eau froide, et bientôt il retourne à ses travaux.

— Quelques années après, le paysan Priessnitz fonde un vaste établissement, où de tous les points du globe accourent une foule de malades, venant demander à l'art empirique la guérison que leur a refusée la médicine.

1. Analyse the last sentence, beginning with *guérison*.

2. Point out instances of imperfect and compound of present in the above, and explain the relation of those tenses to the preterit, respectively.

3. Explain the form of the participle *refusée*, and make a sentence which requires it to be written *refusé*.

4. Give the literal meaning of *lui brise deux côtes, en s'appuyant la poitrine*, and give the rule for such forms.

Render in French: In Greece[1] there was a fountain of which it was said that those who had bathed in it were cured of their love. It is a virtue[2] that it has since lost.

[1] *Grèce.* [2] *la vertu.*

III. Et si vient la pluie, croyez-vous que je perde mon temps? Jamais je n'ai tant à faire. Voilà mille petites rivières qui se rendent au gros ruisseau, lequel s'emplit, se gonfle, mugit, entraînant dans sa course des débris que j'accompagne chacun dans ses bonds avec un merveilleux intérêt. Ou bien quelque vieux pot cassé, ralliant ces fragments derrière son large ventre, entreprend d'arrêter la fureur du torrent.

— C'était la première fois que, la voyant de près, je pouvais me repaître du charme que je trouvais en elle. Que ne puis-je le répandre en ces lignes et la peindre comme elle m'apparaissait. Et encore semblait il que la bibliothèque de mon oncle Tom lui fût comme un cadre merveilleux qui rehaussait son éclatante beauté. Sur les rayons poudreux, ces livres vénérables, représentant la suite des âges, ce parfum de vétusté, ce silence de l'étude, et, au milieu, cette jeune plante toute de fraîcheur et de vie . . . Ce sont choses qui ne se peuvent enclore dans des mots.

1. Explains the forms *perde, s'emplit, fût.*

2. Point out the relative pronouns in the above, commenting on the form of each.

3. In *ce sont choses qui*, etc., why is not *ce* in the plural? Explain that word.

4. Give the principal parts of all irregular verbs in the passage above.

Render in French: This is the house in which we used to live and that I have so often described to you. My uncle's was situated on the same street.

Write a few lines in French about each of the following topics: *Les vendanges. Les pommes de terre. Les bateaux à vapeur.*

IV. *Passage not read before.* Qui trouverait dans une île déserte et inconnue à tous les hommes une belle statue de marbre, dirait aussitôt: Sans doute il y a eu ici autrefois des hommes; je reconnais la main d'un

habile sculpteur; j'admire avec quelle délicatesse il a su proportionner tous les membres de ce corps, pour leur donner tant de beauté, de grâce, de majesté, de vie, de tendresse, de mouvement et d'action. Que répondrait un homme, si quelqu' un s'avisait de lui dire: Non, un sculpteur ne fit jamais cette statue. Elle est faite, il est vrai, selon le goût le plus exquis, et dans les règles de la perfection, mais c'est le hasard tout seul qui l'a faite. Parmi tant de morceaux de marbre, il y en a eu un qui s'est formé ainsi de lui-même; les pluies et les vents l'ont détaché de la montagne; un orage très-violent l'a jeté tout droit sur ce piedestal qui s'était préparé de lui-même dans cette place. FÉNELON.

FIRST YEAR. MAY, 1877.

[EXAMINATION PAPER OF THE THIRD YEAR AT THE ANNUAL.]

Number of students, 24. Average mark, 59.

I. Während des Winters lagen die Kreuzfahrer zerstreut zwischen Philadelphia und Konstantinopel; allmälig zog sie Friedrich aber immer näher an die Hauptstadt hinan, ließ die Befestigungen von Philadelphia zerstören, und gab den Gesandten der Königin Sibylle von Jerusalem und des walachischen Fürsten Kolopetros Gehör. Jene behaupteten (obgleich ohne weitere Beweise), die Griechen wären gesonnen, alle Kreuzfahrer durch Wein und Mehl zu vergiften, und Kolopetros versprach ein Hülfsheer von 40,000 Mann, wenn Friedrich, der römische Kaiser, sich auch die griechische Krone aufsetzen wolle. Noch einmal wies der besonnene Held, um seiner ursprünglichen Zwecke willen, diese einladenden Anträge zurück; aber schwerlich hätte er sich länger allen Launen der Griechen unterworfen. von *Raumer*.

II. Von allen Seiten drangen jetzt die Türken auf die Pilger ein, und die Größe der Gefahr preßte selbst dem standhaften Kaiser den Wunsch ab: „er wolle gern jede andere Noth ertragen, wenn nur das Heer ungefährdet in Antiochien wäre." Als aber die Seinen wirklich anfingen zu weichen, rief der Greis mit lauter Stimme und durch seinen Heldenmuth wunderbar verjüngt: „Warum zögert ihr? Weshalb seid ihr niedergeschlagen? Gottlob daß die Feinde endlich eine Schlacht wagen! Um den Himmel mit eurem Blute zu gewinnen, verließt ihr das Vaterland; jetzt ist die rechte Zeit, folgt mir, Christus siegt, Christus herrscht!" Mit diesen Worten sprengte Friedrich in die Feinde, es folgten ihm seine Mannen, und in demselben Augenblicke gewahrte man die christlichen Fahnen auf den Thürmen von Ikonium. von *Raumer*.

III. a. Seine Ufer und sein Grund bestehen aus kaltem Wasser, während seine Strömung warm ist. Der Golf von Mexiko ist seine Quelle, und seine Mündung liegt in den arktischen Meeren. Es ist der Golfstrom. Es giebt in der Welt keine zweite Wasserfluth, die ihm an majestätischer Größe gleich käme. * * *

b. An Wasserfülle stehen jedenfalls alle dem Amazonenstrome nach, wie er auch der Ausbreitung seines Stromgebietes nach alle anderen weit hinter sich läßt, indem er einen Flächenraum von 112,000 q. M., also ungefähr die zehnfache Ausdehnung von Deutschland einnimmt.

c. Auch die reinste Quelle enthält mineralische Bestandtheile, welche das durch die Sonnenwärme aus dem Meere destillirte und als Regen herniederkommende Wasser auf seinem unterirdischen Laufe aus der Erdrinde ausgezogen.

d. Auch aus heißen Quellen setzen sich oft sehr beträchtliche Massen von kohlensaurem Kalke ab. Es geschieht dies noch rascher, als aus kaltem Wasser, weil aus warmem die zur Lösung des kohlensauren Kalkes nöthige Kohlensäure viel rascher entweicht. Eines der bekanntesten Beispiele für solche Absätze liefert der karlsbader Sprudel, der eine ungeheure Menge von verschieden gefärbten Massen, unter dem Namen Sprudelsteine, vielfach verschliffen und verarbeitet, absetzt. *Pfaff.*

IV. a. Analyze in full the following, stating in the case of each, as also of the parts composing it, whether it be derived or compound: Kreuzfahrer, Befestigung, behaupten, Antrag, Heldenmuth, beträchtlich, Unentschlossenheit.

b. What is the difference between compound and derived words? When a noun is the first part of a compound word, what variations in its form may there be? What are the two modes of forming derived words; the relative frequency of their use? What is the force of the inseparable prefixes ver, and zer?

c. Give the English *historically* connected with the words ziehen, fahren, bringen, fangen, schlagen, Zeit, Theil; with the suffixes -schaft, and -thum.

V. a. Case and construction of Befestigungen, Kaiser, sich (I); Ausbreitung (III, b); welche (III, c)? What is the difference in the use of während in I and III, a? What is the difference in *meaning* and *construction* between von verschieden gefärbten Massen (III, d) and von verschiedenen gefärbten Massen?

b. To what class of the subjunctive belong wären (gesonnen), hätte unterworfen (I); wolle, wäre (II); käme (III, a)? What is noticeable in the *tense* of wären (gesonnen)? What is the difference between the force of käme and the indicative (as would be used in English)?

c. Principal parts of lagen, gesonnen (I); weichen (II); verschliffen (III, d). Is unterworfen (I) a separable or inseparable verb, and why? How does seid ihr niedergeschlagen (II) differ in *form* and *meaning* from habt ihr niedergeschlagen?

VI. a. LEIPZIC, March 24.

Dear Sir: — Your letter was received last week. I beg pardon for not answering the same at once, but was prevented by pressing business.[1] The books of which you speak we have on hand. We will sell them to you at a discount of ten per cent. If you wish the same, please inform[2] me, and I shall take pleasure in filling your order. Yours respectfully.

[1]dringende Geschäfte. [2]benachrichtigen.

b. I overheard[1] this morning our Henry requesting[2] Elizabeth to say; "Heaven be thanked, the table is set," and falling[3] into a violent[4] strife with her when she would not do so. Laughing, I related that to my wife; with flattery[5] I said to her that she would not be so obstinate, and, in jest, begged her to speak those words. She however refused[6] with such decided obstinacy, with such striking[7] stubbornness, that we had a serious altercation.[8]

[1]belauschen. [2]verlangen; who requested. [3]gerathen. [4]heftig. [5]schmeicheln. [6]sich weigern. [7]auffallend. [8]Wortwechsel.

c. Write in German the second stanza of „Die Lorelei." Schreibe kurze Aufsätze über die folgenden Gegenstände: „Die Vögel im Winter;" „Die Windmühlen."

VII. (Passage not read.) Gehen wir noch einmal auf den Vergleich des Auges mit der *Camera obscura* zurück, so fällt uns noch ein besonderer Vorzug des Auges auf, den dasselbe vor jener voraus hat. Er besteht darin, daß die Hinterwand des Auges kugelförmig gewölbt ist, während in der *Camera* die matte Scheibe,[1] welche das Bild auffängt, eben ist. Dadurch erhält aber das Auge zwei wesentliche Vortheile, die jedem leicht auffallen werden, der einmal das Bild einer *Camera* betrachtet hat. *Bernstein.*

[1] disk.

LOWELL FREE COURSES FOR 1876–77.

General Chemistry. Twenty-four laboratory exercises.
Qualitative Analysis. Twenty-four laboratory exercises.

President Runkle ; —

DEAR SIR : — The Lowell Course in Chemistry the present year, although conducted on the same plan as in previous years, has been unusually satisfactory. Many of the applications were made in person, and were from those having a strong desire to avail themselves of the opportunities offered, and the number of really earnest workers seemed to me to be larger than usual. The entire number of persons attending the exercises was fifty-four ; the largest number at any one time members of the two classes was forty-eight ; the average attendance was 36.5. This average may seem rather small, but several circumstances account for it : the weather on two of the days was so very severe that many were prevented from coming, and the school holidays coming during the course caused the absence of many of the teachers who were at the time out of town. The smallest attendance was twenty-seven ; the largest forty-one.

The following statistics may be of interest : —

Number of students in General Chemistry	34
Number of students in Qualitative Analysis	20
Number of male students	32
Number of female students	22

Occupations as far as recorded:

Teachers	26
Physicians	1
Pharmacists	10
Engaged in other business	8
Unknown and Students	9
Total	54

Yours, very respectfully,

WM. RIPLEY NICHOLS.

Elementary Geology. Eighteen lectures.

These lectures began by defining the general principles of dynamical and historical geology, and then proceeded to consider the history of the great geological divisions, as illustrated by the rocks of North America, regard being had both to their geographical relations and to their economic mineralogy.

T. STERRY HUNT.

The Philosophy of Government. Eighteen lectures.

This course was attended by some fifty persons, the majority being men, and a large part of them students of law, or young lawyers. The following is an outline of the topics: —

Lecture I. The Nature of the State: — It is not a contingent combination of individuals, resulting from (*a*) the pressure of external evils, or (*b*) the accident of descent or juxtaposition.

Lect. II. The Nature of the State: — It is not a voluntary organization of individuals for ends merely special, either (*a*) the maintenance of private rights, or (*b*) the promotion of Economics.

Lect. III. The Nature of the State: — It is the investiture of Rational Man with institutions, — the organization of Universal Personality considered in its progressive entirety.

Lect. IV. The Foundations of Sovereignty, as given in the Logical Origin of the State: — Theory of the "Social Contract"; sovereignty not from it.

Lect. V. The Foundations of Sovereignty: — Theories of the "Natural" Origin of the State; it is not (*a*) from Conquest, or other forms of Force; nor (*b*) from the Family; nor (*c*) from the Collective Will of the People.

Lect. VI. The Foundations of Sovereignty: — Theory of Divine Right; the State is founded in Human Nature, *i. e.*, comes from God.

Lect. VII. The Foundation of Rights: — The State is their only sufficient basis.

Lect. VIII. The Nature of Rights and, especially, of Citizenship: — Rights are simply conditions of Personality legalized, and their possession is conditioned upon the actualization of Personality; Citizenship is investiture with Rational Freedom, *i. e.*, with Obedience to Law from Conviction.

Lect. IX. The extent of the State's realm in Human Life, (*a*) by the Social Process, (*b*) by Formal Administration.

Lect. X. The function of the State in Education, Morals, and Religion.

Lect. XI. The Form of the State, as distinguished from its Substance; the Medium of the Form, as distinguished from its Sovereignty. The two main Forms, — the Realm and the Commonwealth.

Lect. XII. The Liability of the Realm to antagonize the State, (*a*) as Autocracy, (*b*) as Empire, Tyranny, or Cæsarism, (*c*) as Oligarchy, (*d*) as Democracy.

Lect. XIII. The nature of Constitutions; the Hereditary Principle as the basis of distinguishing the Kingdom from the Republic.

Lect. XIV. The ultimate Distinct Functions in the State.

Lect. XV. The true nature of Representative Government: the Representative stands for the Civil Idea, not for Constituents.

Lect. XVI. The basis of Suffrage: — Three questions: (1) What warrants the vote as a right? (2) To whom does the right belong? (3) By what polity shall the right be kept with those to whom alone it belongs?

Lect. XVII. The Statutes and the "Higher Law."

Lect. XVIII. The Literature of Political Philosophy.

GEO. H. HOWISON.

Department of Mechanics. Eighteen Lectures.

President J. D. Runkle : —

Dear Sir : — Before determining upon the subjects of the separate lectures in the course on Practical Mechanics, given by me in the autumn of 1876, I consulted a number of gentlemen who conduct manufacturing establishments in this vicinity, and who have large numbers of workmen under their charge, so that I might make use of the light thus obtained to select such subjects as seem most suitable for mechanics, for whom the lectures were specially intended. I received from many of these gentlemen not only advice, but also the loan of specimens and working drawings. I have to thank, especially, Mr. Boyd, Engineer of the Atlantic Works, E. Boston, Mr. Leach, General Manager of the Hinckley Locomotive Works, Mr. Fairbairn of the Hartford Insurance Co., and Messrs. Richards and Crooker of the Bay State Iron Works. I also took pains to inform the Superintendents of a number of shops of the projected lectures, and to request them to call the attention of their employees to them. The largest number present at any one lecture was eighty, the average attendance being twenty-five or thirty. The subjects actually selected were as follows :

I. Strength of shells, tubes, flat and cambered ends of Steam Boilers, Copper and Cast Iron as used in Boiler Making.
II. Wrought Iron and Steel.
III. Riveting and Welding.
IV. Description of main types of Steam Boilers and essential differences.
V. Construction of Boilers.
VI. Furnaces and Boiler Setting.
VII. Furnace and Boiler Fittings.
VIII. Wear and Tear and Incrustation.
IX. Boiler Explosions.
X. Boiler Power and Combustion of Fuel.
XI. Steam Engine Indicator.
XII. " " "
XIII. Governors.
XIV. "

XV. Belting. — Materials used — Forms of Pulleys — Crowning of Pulleys — Lateral Stiffness of Belt — Engaging and Disengaging — Fast and Loose Pulley — Quarter Twist — Guide Pulleys, etc.

XVI. Velocity ratio in Belting — Speed Cones — Eccentric Pulleys — Wire ropes.

XVII. Strength of, and Power transmitted by Belts and Wire ropes.

XVIII. " " " " " " "

Very Respectfully,

GAETANO LANZA.

ABSTRACTS OF THESES PRESENTED BY GRADUATES OF 1876–77.

DEPARTMENT OF CIVIL ENGINEERING.

The Central Avenue Bridge, Dorchester, Mass. Abstract by the author, H. H. Carter.

This bridge, which is built in two spans of 94 ft., and 63 ft. 6 in. respectively, crosses the Neponset River at Central Avenue, Dorchester, Mass. Each span consists of six wrought iron, single intersection, lattice girders, placed 8 ft. 4 in. apart on centres; the girders being connected at the top and bottom chords by lateral bracing, and at the ends and intermediate points by vertical cross bracing. The girders in both spans are 6 ft. 5 in. in depth, resting at their abutment ends on wrought iron rollers, and at their pier ends on cast iron bearing plates.

Both chords are of T-shaped section, built up from wrought iron plates and angle irons. The web members consist of angle irons riveted to the vertical web plates of the chords, and also to each other at intersection points. The floor timbers rest on the top chords of the girders, and are of yellow pine, fifteen inches deep at the centre of the roadway, and twelve inches deep at the sidewalk curbs. Alternate floor timbers project over the outside girders in order to support the sidewalk, and are six inches in width, the remaining timbers being four inches in width. The roadway planking is in two courses; the lower course is of yellow pine four inches thick, spiked to

the floor timbers; the upper course is of spruce two inches thick, spiked to the lower course.

The long span was taken for detailed investigation, and the stresses arising from a live load of 100 lbs. per sq. ft. and a dead load of 50 lbs. per sq. ft. were calculated; also the stresses produced by a 20 ton wagon placed in various positions upon the bridge.

The maximum stresses in the different parts of the girder having been found, the necessary dimensions have been calculated and compared with the actual dimensions used in the construction of the bridge. Accompanying the description and calculation of the bridge are two sheets of drawings, showing the details of construction and the manner of connecting the various parts.

Sea Walls of South Boston Flats. Abstract by the author, Martin Gay.

Accompanying this thesis are two sheets of drawings, one showing the location of the walls, and their relation to the harbor and wharves of Boston, and the other showing on a larger scale the shape of the dock which the walls enclose, and sections of the different kinds of wall used.

I have explained that this project was intended only as an improvement to the navigation of the harbor, and the reasons for its being undertaken, and that it was finally extended into a scheme for reclaiming the useless flats of the Commonwealth; also the methods of filling the flats with the material dredged from the harbor.

Next, I have described the form and materials, and have calculated in turn each wall; investigating first, whether the wall of itself is strong enough to resist the forces acting upon it, and second, if the foundation upon which the wall rests will bear the load put upon it.

The Lowell Water Works. By Joseph P. Gray.

(Abstract not received.)

The Charles River Bridge at Newton Upper Falls. Abstract by the author, Edward Grover.

The subject was treated under the following different headings:

I. The Location and general description. II. Materials and Construction; with explanation of drawings. III. Calculation. Strength and Stability. IV. The Centering.

The Sudbury River Aqueduct for bringing an additional supply of water to Boston was begun in July 1875, and at the time of writing was in different stages of construction. The line from Farm Pond in Framingham to Chestnut Hill reservoir is 15.61 miles long, and is an interesting example of construction in swamp and quicksand, of rock and earth tunnelling, and of cuttings and embankments.

The most important structure on the line is the bridge which carries the conduit over the valley of the Charles River at Newton Upper Falls. This bridge is 475 ft. long between the terminal chambers. At the westerly end is a semi-circular arch of 37 ft. span, partly cut off by the slope of the hill which is quite steep. Next is a segmental arch of 130 ft. span and about 45 ft. rise, radius 69 ft. Then there are on the east side of the river, four semi-circular arches of 37 ft. span and lastly, a flat arch having a span of 28 ft. over Ellis St., a town way. In making the surveys there were two schemes for crossing the river under consideration; namely, by a bridge as located and by means of a siphon about a mile from the former. The cost was nearly the same for each and the Water Board decided to build the bridge. The river at this point is quite narrow, a little over 100 ft. wide and the slopes of the valley, especially the westerly bank, being abrupt and the river bed and banks of firm rock, making a good foundation for the piers and abutments. The springing of the large arch is considerably above

the water-level which latter varies but slightly during the year; accordingly there is no obstruction of the water way. The width of the bridge just below the conduit is 18 ft., the face walls having a straight batter of one in twenty-four, except for the great arch which has a curved batter, being the curve of presures. It is the largest stone bridge in the country, with one exception, and is a model of strength and beauty.

The construction is next described in the following order. (1) Foundations, (2) Piers, (3) Voussoirs, (4) External Spandrel walls, (5) Interior Spandrel, filling, &c., (6) The Conduit, dimensions and construction, (7) Terminal chambers, manholes, (8) Approaches, including a description of the materials and their composition and a description of the accompanying drawings.

The foundations consist either of the natural rock or of large blocks of granite laid at such depth as to be sufficiently firm. The steep western slope and the river bed are composed of a compact granitic rock. The western slope was prepared by removing the soil and loose rock and dressing the solid rock with the hammer to plane surfaces perpendicular to the thrust of the arch at the springing, and level or vertical elsewhere, thus forming sets of steps. The bed of the river was prepared as follows to receive the vertical timbers which supported the centring: The mud was removed and blocks of stone laid on the natural rock; levels were then taken at each point of support and the top of those blocks were made as nearly level as possible; timbers were next laid horizontally, the lower surfaces being cut to fit the stone so as to bring the upper surfaces exactly level. The slope on the easterly shore was neither so steep nor so rocky, and the earth was simply excavated a few feet to receive the large rectangular blocks of stone laid as above mentioned, each block being smaller than the one below it to distribute the pressure over a larger area.

The piers are composed of very large rectangular blocks of ashlar with dressed beds, builds, and vertical joints and well bonded together. The faces are built with a batter and the

caps are of a little lighter colored stone. The foundations, piers and centring having been completed the arches were begun and carried up, keeping at the same height on each side, so as to keep the load on the centring symmetrical. The keystone has a depth of five feet and the springing stones a depth of six ft. for the great arch.

The voussoirs are hammered smooth, the intrados to the curve and the ring and coursing joints to plane surfaces, leaving no cavities. In the large arch the faces of the voussoirs are bounded by neat lines three inches distant from the plane of the spandrel wall, and the projection is chamfered off at 45°. The voussoirs of the roadway are also chamfered, the projection being two inches.

The exterior spandrel walls are twenty inches thick at the top and increase to twenty-four inches at the springing of the small arches, below which they are twenty-four inches. The face stones are quarry faced and a certain part of the walls are of split stone, all well bonded together. Between the two exterior spandrel walls are two walls of brick laid in mortar. These are eight inches thick and are tied together and to the exterior walls by long bond-stones. They are also covered on top with split stone which supports the conduit. Near the top of these walls, the spaces between are arched over, thus forming continuous passages between the arches by which access may be had under the conduit. These passages are lighted and ventilated by narrow openings in the spandrel under the lower string course. Part of the space between the spandrels is filled with cement concrete. Great care was taken in the designing and construction to make the conduit as nearly as possible water-tight, and also to provide for the thorough drainage of any water which might leak through. The floor of the passages above mentioned is cemented, and then in order that any percolation may not effect the spandrel walls the water is conducted over the concrete filling, which is covered with a coating of coal-tar concrete, to gutters in or near the centre of the piers and runs out at "weeping holes" at the springing of

the arches. The cross section of the bridge is like that of one of the bridges on the Croton Aqueduct in New York.

The conduit is of good size, much larger than the old Cochituate conduit, the sectional area being equivalent to a circular section of 8½ ft. diam. It is estimated that it will deliver at the rate of seventy millions of gallons in twenty-four hours. In the thesis was a sketch of the section showing the curves of the inside, etc., as also a sketch of the Croton aqueduct, with which it was compared. The manner of building the conduit on forms was described. The whole of the curved brick lining was coated both inside and outside with coal-tar concrete, and when finished, an additional coating of pure Portland cement one-fourth inch thick was applied over the inside. The side walls outside the curved brick lining are of brick having an air space running through the centre of each. These walls are covered with a coping of smooth cut granite. This coping or upper string course together with the lower string course of similar stones just below the conduit are a great addition to the architectural beauty of the bridge. The side walls of the conduit are covered with these coping stones between which and the top of the covering arch the filling is of cement concrete with a layer of coal-tar concrete. This with the coping forms a water-tight roof and a splendid promenade for moonlight nights. There is an ornamental iron fence over the whole length. The exterior of the conduit walls is of face brick formed into panels which gives a very pleasing effect.

The terminal chambers are somewhat different in construction and contain a manhole in each for access to the interior of the conduit. The internal passages of the bridge are entered by a trap-door at the foot of the roadway arch. The bridge is terminated by a series of steps, of the smooth light granite like the coping, which will prevent the bridge being used as a drive. The accompanying drawings consist of a side elevation and different sections, cross and longitudinal, at different points through the large and small arches. Also plan elevation, and sections of the terminal chambers.

Calculation. In designing an arch of masonry, many points have to be considered in order to assure sufficient strength and stability. The load to be supported is generally known, to which, having assumed the form, we have to proportion the rise and span which are both somewhat limited, and also to determine the thickness of the arch-ring both at crown and at springing, the height to which the backing must be carried, etc. In this class of structures there is almost always some similar work already in existence which may be imitated or modified to suit the requirements, but we ought to know, especially in any new case when we may not obtain from experience and analogy the necessary information, exactly what are the actions which are produced in an arch by different manners of loading, etc. In other words we want to know the form of the curve of pressures. This we may do by means of a graphical construction, or by analytical formulæ we may obtain the point in the arch ring where the line of pressures passes near or beyond the edge of the voussoirs. In the present case where the relation between the form of the arch and the load could not be easily expressed, the point of rupture and maximum horizontal thrust was found graphically according to the method of Rankine. The method of Dr. Scheffer was also used and compared with Rankine.

The Centring. In calculating the greatest normal pressure that can come on any segment of the arch, with exactness, friction ought to be taken into account, as also the fact that the normal pressure of any voussoir upon the centring is decreased the more the arch stones are laid above it, since the normal component of the tangential thrust due to the voussoirs above acts outward and opposite to the normal component of the weight of the voussoirs considered. According to Rankine friction should be disregarded, as the action of the voussoirs when completely laid to the keystone is nearly the same whether friction acts or not. But what is required is to find the greatest normal thrust on any one segment which would not occur when the whole arch was complete. However for practical purposes,

neglecting the friction, the calculations, as Rankine says, would err on the safe side. Then the only way to proceed appears to find the normal thrust for each stone separately which process must be omitted in the abstract. A drawing of the centring of the large arch was inserted in the body of the thesis. The whole cost of the bridge was $174,105.75.

The Double Lattice Parker Iron Bridge across the Merrimack River at Lowell. Abstract by the author, Richard A. Hale.

A brief sketch of the old bridge and reasons for changing are given, and then a description of the abutments and new bridge.

The present bridge consists of two iron Parker girders, each of about 150 ft. span, 40 ft. wide, and 20 ft. in height in the centre, with curved upper chords and horizontal lower chords. The girders are commonly known by the name of "Hog-back." One span was taken for discussion. As no drawings were available, complete measurements were made of the bridge, from which the weight of the structure was calculated.

From this data the dead load was taken as 20 lbs. per square foot, and the live load as 60 lbs. per square foot. The methods of obtaining the maximum stresses in the chords, diagonals and uprights, were explained, and the maximum stresses of all the parts given in tabular form. The sectional amount of material in each piece was compared with the sectional amount required to resist the stress, and the strength of all the rivet and pin connections were calculated. The cross girder for sustaining the road-way is an iron Pratt truss, with projecting ends for sidewalks. The method of finding the maximum stresses in all of the parts were given, and the stresses were arranged in tabular form, together with the sectional areas required, and the actual sectional area. The strength of the connections were also calculated. In the calculation for the floor stringers, a concentrated load of twelve tons was taken on each stringer, and the resistance computed. For sway bracing the wind was

considered as acting uniformly on 500 square feet with a force of 20 lbs. per square foot, and the strength of the rods calculated.

Two drawings were made, one containing the plan and elevation of the bridge, and the second containing the details and connections on an enlarged scale.

Highway Bridge across the Merrimack River, between Groveland and Haverhill. Abstract by the author, George W. Kittredge.

The thesis begins with a short history of the unsuccessful attempts in 1834, 1835 and 1836 to obtain a charter to build a bridge where the present one stands.

The bridge, as erected, consists of six spans of 124 ft. each, besides a draw span of 48 ft. It is a bowstring girder in form, and was built by the King Bridge and Iron Manufacturing Company of Cleveland, Ohio. The different parts of the structure are next described in the following order: (1) The cribs upon which the piers rest; (2) The piers; (3) The abutments and wing-walls; (4) The superstructure. The calculations are made and explained upon the supposition that when a bowstring girder is uniformly loaded over its entire length, the load is transmitted directly to the arch through the verticals. A table accompanying the calculations gives the total load, the required sectional area, the actual sectional area, the safe intensity of stress and the actual intensity of stress on each of the pieces calculated. In the conclusion are set forth some of the greatest objections to the structure, and the manner in which they might have been obviated to a certain extent.

The New Bedford Water Works. Abstract by the author, C. F. Lawton.

The advantages furnished by an abundant supply of fresh water, on the score both of health and economy, are first spoken of. I have then entered into many general questions of

water supply — the portion of rain-fall available, the measurement of the same, the quality of water, methods of analysis, etc. I have then given a short history of the New Bedford Water Works, and noticed particularly the questions of which a general discussion has previously been given. The construction of many parts of the works, such as the dams, waste-weirs, aqueduct, etc., has been explained minutely, and has been accompanied by drawings.

The discussion of the pumping engines has been left, as being more suitable for the mechanical engineer; and the subject of the distribution of the water requires too much space to be treated of in this thesis.

The Lawrence Water Works. Abstract by the author, B. C. Mudge.

The supply of water to large towns has become a subject of so great importance, and involves problems of so extensive and complicated a nature that the best skill and attention of scientists and practical engineers have been called into requisition in its treatment.

In supplying this indispensable element of health and comfort to a large city, water is drawn, in many cases, many miles distant; it has to be purified and filtered for domestic use; elevated often to a height of hundreds of feet above its original level, and finally distributed through nearly every street, and into the interior of almost every house. It will therefore be easily conceived that the operations accomplishing these objects require in arrangement and adaptation no small degree of scientific and technical skill.

A short account of the earliest instances of a water supply to cities, other than by natural means, particularly those of Jerusalem and Rome, together with a mention of the Assyrian, Persian and Egyptian peculiarities relating thereto, served to introduce the subject. The hygienic necessity of a disjunction of the sewage waste and water supply, with some facts con

nected with the pollution of the water of the Thames, was urged from many standpoints.

The various sources and qualities, modes of conducting, purifying, pumping, storing and distributing the water, were the chief topics for consideration, each subject receiving separately its due amount of attention. The quantity, quality and methods of rendering the relative values of their determinations in a given district serviceable, were presented. Granting these principles relating to water supplies in general to be in the main correct, a description of the Lawrence Water Works, showing how far they conform thereto, practically illustrating many of the facts adopted, was undertaken, from a knowledge derived by a personal study of the drawings and works themselves.

With the Merrimac River as the source of supply, there seemed to be no limitation to the amount to be obtained, and in the year 1873 the first steps were taken to prosecute the work.

DESCRIPTION.

There is an inlet pipe admitting water directly from the river to the wells of the pumping station, one hundred and seventy feet long, constructed partly of brick masonry and cast iron pipes thirty-six inches in diameter. A filtering gallery was introduced along the bank of the river to provide, in certain seasons of the year, a supply of filtered water whenever the water of the river should become turbid. This is of granite foundation, with an arch of brick masonry. The pumping engines were built by S. P. Morris & Co., from the designs of E. D. Leavitt, Jr., of Cambridge, Mass. They are overhead beam engines, with compound cylinders. The force main is a line of cast iron pipes thirty inches in diameter, extending through a tunnel of brick masonry nine hundred feet in length to the reservoir.

The reservoir is rectangular in form, seven hundred and thirty feet long, four hundred and eleven feet wide, with a division embankment, and capable of containing 40,000,000

gallons when filled to high water mark. Upon this division wall is an over-fall, for the purpose of aerating the water. One peculiar and very valuable advantage these works possess above most others is, that both systems of distribution can be employed at will; that of pumping directly into the street mains the water to be delivered finally into the reservoir; also that of pumping directly into the reservoir through the force main, thence to be delivered to the inhabitants.

The Newton Water Works. Abstract by the author, A. L. Plimpton.

In this thesis the general questions, which always have to be considered before establishing a system of water works, are discussed in the first pages in their important points. They are, namely, the questions of quantity, quality and the most available source or sources of supply. At the same time these questions are applied to the particular case of Newton. Its most available source was the Charles River, which now supplies the city.

In regard to economy, the plan adopted by Newton was the Reservoir and Pumping System, or Gravity Plan.

After these matters, a general description of the works is given. They consist of the Filtering Basin, the Pumping Station, the Reservoir, together with the various pipes and conduits which connect the same, and lastly the Distributing Pipes.

THE FILTERING BASIN.

It is about 1000 feet long, the cross section being 70 feet on top and 10 feet at the bottom. It follows the general direction of the river and will probably be extended up the river before long.

An iron pipe connects the basin with the pumping station. The plan of the pumping wells is shown by a drawing. The Worthington Pumping Engine is used, and the water has to be lifted about 170 feet.

THE RESERVOIR.

This is of irregular form adapted to its position on a side-hill The embankments are well built, and are covered with a slope wall of blocks of granite on the inner side. The specifications for the work throughout were very strict and were followed very closely.

The reservoir is partly in excavation and partly in embankment, it being so placed as to make the quantity of material removed about equal to that required for the embankments.

In excavating, the method of "Falls" was used. The gain of this, in regard to the amount of work required, over the old way of working it all with picks, is discussed; and assuming a certain size for the fall which is about that usually taken, the result shows that it does not require quite half the time, with the same amount of labor, to completely break it up ready for the shovellers.

In obtaining the capacity of the reservoir, the area of the bottom was calculated by the method of coördinates. I then found the contents, assuming the sides to rise vertically. But as the sides have a slope of $1\frac{1}{2}$ to 1, there is an additional amount to be taken in, whose cross section is a triangle. As this cross section is constant I used the Theorem of Pappus. The reservoir holds about 14,600,000 gallons.

THE GATE CHAMBER.

The arrangement of the pipes in the gate chamber is such, that while the engine is working, the supply in the distributing pipes is obtained without its passing into the reservoir first. But when it is not working, the supply is again taken from the reservoir. To effect this result a single pipe serves both as the inlet and outlet of the reservoir, arranged with automatic valves.

Iron pipes were used throughout, and the methods for ascertaining the necessary thickness is discussed in the thesis. It is a matter about which there is considerable variance of opinion and many different formulæ are given. The thickness, of

course, depends upon the head and the desired diameter. We find these involved in most of the formulæ and also various constants determined by experiment. Rankine's formulæ are the two following.

$$\left.\begin{aligned} t &= \sqrt{\frac{D}{48}} \\ t &= \frac{HD}{12{,}000} \end{aligned}\right\} \text{ the largest result to be used.}$$

It is found that either of these give a very low result. The formula adopted for the Newton Water Works is the following

$$t = (.00008\ H\ D + .01D + .36) \text{ inches.}$$

H = the head in feet. D = the diameter in inches. As an illustration of the different results obtained by using the above formulæ I give the following. For a 12″ pipe with a head of 200 ft, the Newton Formula gives t = .67 of an inch. Rankine's Formulæ gives t = .50 of an inch. The very systematic way of tabulating the subject adopted at Newton, I have shown in the thesis.

Oftentimes a pipe will be thicker than is necessary because it is better not to have too many classes, and rather than for a small amount of pipe to have a different size, it is placed with the size next thicker.

Design for an Iron Railway Bridge, with a consideration of the Principles determining the Design. Abstract by the Author, George F. Swain.

The purpose of this thesis is to design an iron railway bridge, and to discuss the general principles involved. The total span to be bridged, together with the various local circumstances, being assumed, the economical number of separate spans is first taken up and discussed in its general aspect, and afterwards theoretically, Thurin's formula being explained and applied to the present case. The number of spans having been determined upon, the type of bridge to be employed next engages attention, and the panel length having been assumed in

accordance with the best practice, an extension of "Bramwell's method" is employed to determine the economical depth and the corresponding amounts of iron in all the trusses in common use in the country. This comparison, although made for this particular case only, gives results which are believed to be approximately true for all cases, as regards the order of economy of the different trusses under like conditions. They agree admirably with the best practice, and indicate as the most economical form of truss, the Pratt, with double intersections, a truss extensively used both at home and abroad. This type being adopted, the amount and distribution of the load are next considered, and the accuracy of the usual uniform loads assumed for bridges of this span is tested by comparing the chord stresses produced by them with the actual stresses produced by a heavy train. The details of calculation of stresses and determination of dimensions are then taken up.

Two sheets of drawings accompany the thesis.

The Ashtabula Bridge. By Frank E. Wiggin.

(Abstract not received.)

DEPARTMENT OF MECHANICAL ENGINEERING.

A Review of a Continuous Brake Trial. Abstract by the author, William H. Beeching.

I have considered this subject under two parts: —

Part I gives a description of the trial-ground, the apparatus used, the trains and brakes, the experiments as they took place under the different classes, the statement of the questions to be considered, and, if possible, to be settled by this trial.

Part II deals with the calculations and questions as stated in Part I; also contains tables, with the results obtained, a number of diagrams used in the discussions. We find that the Westinghouse Automatic Brake out-did all the other brakes, in ease of application and running, promptness of action and

apparent durability. We also find that wet rails greatly decreases the coefficient of friction of the brakes, and thus their efficiency when wooden brake blocks are used, and more so than in the case of cast iron blocks.

The Westinghouse Air Brake. Abstract by the author, George W. Chapman.

The Westinghouse Air Brake is a contrivance consisting essentially of a cylinder, fitted with a piston working air-tight within. The piston rod is connected with the brake levers, and on the admission of compressed air, the piston is forced from its normal position at one end of the cylinder to the other. This movement of the piston through about ten inches, and with a pressure of ninety pounds per square inch behind it, is capable of exerting upon the wheels the same, or greater, pressure than is applied by the total weight of the cars resting upon them. The sudden resistance to the train's motion enables it to be stopped under the most adverse circumstances of speed, incline, and weather within a distance of five hundred yards, and ordinarily within five hundred feet. With the old form of hand brake, the train often runs a distance of half or three-quarters of a mile before stopping.

The air pump for compressing the air does not differ materially from the pumps used in physical experiments, but all the appendages are of necessity much stronger. The motive power is a steam engine situated directly over the pump cylinder, so that the same piston rod serves for both. The air is compressed to a pressure of from seventy to one hundred pounds per square inch, and is stored for use in a cylindrical boiler-iron reservoir, situated under the foot board on the locomotive. The details of engine, pump and brake, are numerous, but not complicated for a contrivance of such inestimable value to railroad companies for the safety of the traveling public. It seems to me that in point of simplicity and efficiency in [illegible] brakes, the acme has been attained in the Westinghouse [illegible].

Double Valves as applied to the Rider Engine. Abstract by the author, Linus Faunce.

The Rider Engine is similar to most stationary engines with the exception of the valves and their connection with the governor. The main slide valve is, on its face side similar to the ordinary D valve except that it has its ends lengthened to admit of ports being formed outside of the valve proper. The ports on the face side are parallel with the ports in the cylinder and at right angles to the motion of the valve. On the back these ports are oblique and at opposite angles to each other. The expansion valve is a sector of a cylinder with its acting ends cut off obliquely in opposite directions corresponding exactly with the obliquity of the ports in the back of the main valve. It is fitted into a semicylindrical recess in the back of the main valve.

These valves are operated lengthwise by separate eccentrics, to which they are attached in the usual manner, except that the expansion valve rod has a swivel joint to permit of partial rotation, and it is so connected with the governor that when the governor rises or falls it will be made to rotate in one direction or the other.

The governor, instead of throtling the steam, regulates the point of cut off, making admission longer or shorter as there is more or less work to be done.

With proper proportioned valves and governor any degree of expansion may be obtained.

The Construction and Use of a Mercury Column. Abstract by the author, Chas. H. Fisher.

It is becoming common as more accurate results are required, for engineers to frequently test the instruments which they use in observing pressures. To do this they must, directly or indirectly, compare them with an open air mercury manometer.

In this paper, the necessary principles of the construction of

such an instrument and the interpretation of its readings, are discussed.

The ordinary pressure-indicating instruments are graduated to even pounds per square inch and may be read to the nearest tenth of a pound by estimating the tenths by the eye.

Therefore if we should, in the use of such a manometer, for the sake of convenience, introduce a small error in our interpretations, we may be certain that our result is as near as the instrument on trial can indicate, if we are sure that the error we introduce does not amount to a half of a tenth of a pound.

In using a mercury column there are two ways in which errors may be introduced. The first is in the graduation and reading of the scale with which we observe the height of the mercury. By care, this error may be kept within almost any limit we desire.

The second way an error may arise, is in the transformation of the pressure, expressed in height of mercury, to that expressed in pounds per square inch.

The pressure, in pounds per square inch, corresponding to a column of mercury h inches high, is $p = hy$, where y is the weight in pounds of a cubic inch of mercury. The value of y may vary either from a change of temperature or from the compression produced in the mercury by pressure.

In this paper are discussed the effects of these variations and the means of correcting them.

Finally, there is described a design for such a column, and a suggestion made concerning an addition, to be made to the design, for the purpose of reading the height of the mercury.

Boiler Incrustation. Abstract by the author, Joseph Kirk.

Incrustation in steam boilers is caused by impurities in the feed-water, which become concentrated in the boiler, and finally form a coating or layer on the plates or tubes. The deposit thus formed, having a low conducting power, hinders the transmission of heat from the fire to the water, involving

the expenditure of more coal than would be used if the plates and tubes are clean. The deposit also acts injuriously upon the boiler by causing the plates to be overheated, in consequence of which they may be burned, or their strength may be made insufficient to resist the pressure of the steam. If the deposit on an overheated plate is suddenly cracked off, or removed in any way, the water in the boiler is brought into contact with the plate, and the result may be a true explosion. Substances forming deposits may be divided into two classes; those dissolved by the feed-water, and those held in suspension. To the first class belong salt, lime, magnesia and iron salts; to the second, sand, mud, and vegetable matter. The method of prevention generally adopted against salt are blowing off and surface condensation. Lime is found as incrustation in two forms; carbonate and sulphate. The carbonate may be precipitated before the water enters the boiler by boiling the water, or by mixing it with lime-water. Sulphate of lime is precipitated by being boiled at a high pressure. Magnesia occurs as the carbonate and acts in a similar manner to carbonate of lime. Iron salts have a corrosive action on the boiler. They can be precipitated by boiling. Members of the second class can be removed from the feed-water by filtering. Chemical substances, especially carbonate of soda, are sometimes used in the boiler for preventing lime incrustation.

Substances having, or supposed to have, a mechanical action in preventing incrustation have been used. They often contain grease, which if present in considerable quantity is injurious to the boiler. Vessels for collecting the sediment and preventing it from being deposited on the plates or tubes are sometimes used in the boiler. When a hard coating of scale has formed it may be removed by being chipped off, or by suddenly heating or cooling the boiler. The first method is inapplicable to multitubular boilers unless the tubes are taken out. The second is liable to injure the boiler by the sudden strains introduced. The general opinion of railway men in regard to the prevention of incrustation, is that it is best to

purify the water before it goes into the boiler rather than to use chemical powders, etc., in the boiler.

On Link Motion. Abstract by the author, Cecil H. Peabody.

The idea pursued in this thesis is to take an example of link motion from actual practice, and by applying to it the different methods of working out the problem, to make a comparison of the methods and of their results, pointing out the advantages and deficiencies of each method. As an introduction, there is given a short sketch of the development of the link motion from earlier forms of reversing motions, together with a description of the form common to American practice.

The three methods applied to the problem chosen are, in order, the algebraic method, based on cinematical principles, the graphical method, and the method by use of a model with adjustable parts. The algebraic method is that given by Professor Gustav Zeuner in his treatise on Valve-gears, the problem being solved in full, both numerically and by aid of a diagram, thus obtaining an efficient check on the work. The graphical method is that given by Wm. S. Auchincloss in his Link and Valve Motions, only the simplest case being touched upon. A description of a model at the Hinkley Locomotive Works, with an account of an experiment, giving results, closes the discussion.

DEPARTMENT OF MINING ENGINEERING.

The Vershire Copper Ore and its Metallurgical Treatment. Abstract by the author, George Bartol.

This thesis is divided into six parts.

1. Description of the ore and its constituent minerals. The composition of the ore was found to be: —

Cu	11.39 per cent.
Fe	46.76 "
S	33.98 "
SiO_2	5.67 "
Zn	1.37 "
Co and Ni undetermined.	
Pb, Al_2O_3, Ca, Mg, traces.	
	98.95 per cent.

2. A review of the advantages and disadvantages of the principal methods for the extraction of copper. Outline of the process best suited to this ore and of the one finally adopted.

3. A detailed account of the metallurgical treatment of the ore at the Institute. 1019 lbs. of the ore were treated in the following manner —

a. Roasted in a reverberatory furnace.

b. Roasted ore smelted in the blast furnace for matte.

c. Matte roasted in a kiln.

d. Roasted matte smelted in the blast furnace for black copper and matte.

e. Matte roasted in a reverberatory furnace.

f. Roasted matte smelted in crucibles for black copper and matte.

The products were: — 97½ lbs. of black copper and 2 lbs. of matte.

4. Tables giving details of furnace runs, consumption of fuel, losses of copper, etc.

5. Remarks on the size and position of tuyères, deductions from tables, suggestions and conclusions.

6. Description of the methods employed in chemical analysis.

Investigation of the Institute Ore-washers. Abstract by the author, W. C. Flint.

This report is of an examination of the work on a low grade ore from the Merrimac Mine by the ore-concentraters at the Mass. Institute of Technology, being a counterpart to the thesis of Mr. Stimpson, but not covering the same ground.

This thesis is divided into six parts.

Part I. A statement of the object of the thesis. A review of the character of the ore and the difficulties of its treament, owing to the presence of minerals of every specific gravity, from 2.5 to 7.5. A brief description of the Spitzkasten, also of the Rittinger (side-bump) and end-bump tables and dolly-tub.

Part II. Narrative of the experiments in running the machines. Tables of the records kept, also a table showing the order of operations on the ore. A statement of the final products.

Part III. A consideration of the machines from a business point of view. The proportion of metal-bearing ore saved. The cost of running the machines compared with the assay value of what was saved. The value and amount of ore saved.

Part IV. A discussion of the forces which act on bodies falling in water, also the formulæ deduced for the velocity, path, and time of fall of both spherical and irregular bodies; being the theory of grading. (Translated from Rittinger's "Lehrbuch der Aufbereitungskunde.")

Part V. Investigation of the products of boxes 2, 3, and 4 of the Spitzkasten, and of the overflow of the same, as follows:

Samples were taken and passed through sieves to size them. The sieve products were grouped into a smaller number of divisions, thus: Spitzkasten, box 2, into four: 1, through a 12th sieve on a 40th; 2, through a 40th on a 70th; 3, through a 70th on a 120th; 4, through a 120th; box 3 into three: 1, through a 12th on a 70th; 2, through a 70th on a 160th; 3, through a 160th; box 4 into three: 1, through a 12th on a

120th; 2, through a 120th on a 160th; 3, through a 160th; overflow into two; 1, through a 12th on a 160th; 2, through a 160th.

Construction of curves to show the results of this sizing. The above divisions examined for PbS, S, Fe and CO_2, and the mineral percentages calculated therefrom. Account of the analyses and results. Construction of curves to show these graphically. Tables showing the direct results of analyses, also the mineral percentages.

TABLE OF DIRECT RESULTS.

		Per cent. PbS.	Per cent. S	Per cent. CO_2.	Per cent. Fe.
Box 2 of Spitzkasten.	Division 1.	1.96	1.83	6.17 5.96	7.17
	" 2.	2.10	2.33	6.89 6.72	8.25
	" 3.	5.25	5.05	9.73 9.42	12.42
	" 4.	15.42	8.08	9.23 9.31	18.11
Box 3 of Spitzkasten.	" 1.	2.61	1.82	4.85	6.58
	" 2.	4.56	2.68	7.89	8.09
	" 3.	8.63	6.92	9.48	13.82
Box 4 of Spitzkasten.	" 1.	1.69	1.80	4.15	4.64 4.75
	" 2.	2.87	1.97	7.40	8.86
	" 3.	9.90	5.74	9.78	12.65
Overflow of Spitzkasten.	" 1.	4.70	3.895 3.95	6.60	7.62
	" 2.	9.65	3.42 3.49	8.82	9.76

TABLE OF MINERAL PERCENTAGES.

		Per cent. Galena.	Per cent. Pyrite.	Per cent. Siderite.	Per cent. Gangue.	Total per ct.
Box 2 of Spitzkasten.	Division 1.	1.96	3.94	16.37	75.43	96.80
	" 2.	2.10	3.54	17.92	71.70	95.56
	" 3.	5.25	8.14	35.23	59.48	98.13
	" 4.	15.42	11.27	24.44	48.80	99.93
Box 3 of Spitzkasten.	" 1.	2.61	2.76	12.78	77.15	95.30
	" 2.	4.56	3.58	20.90	69.88	99.12
	" 3.	8.63	10.80	24.99	49.39	93.81
Box 4 of Spitzkasten.	" 1.	1.69	2.01	10.94	83.55	97.99
	" 2.	2.87	2.98	19.51	71.69	97.05
	" 3.	9.90	8.46	25.78	53.18	97.32
Overflow of Spitzkasten.	" 1.	4.70	6.17	17.40	70.84	98.61
	" 2.	9.65	4.14	33.26	51.94	98.99
Calculated from the above table and the weights of each product.	Total Box 2.	5.98	6.69	21.45	63.78	97.80
	" " 3.	6.88	7.58	32.55	50.66	97.12
	" " 4.	8.05	7.02	24.02	58.47	97.56
	Total Overflow.	9.32	4.28	22.86	62.49	98.95

The residue insoluble in HNO_3 and $KClO_3$ was weighed and called the amount of gangue.

Part VI. Conclusions drawn from the results obtained in Part V, considered together with the theory given in Part IV. Suggestions as to the reasons why the spitzkasten did not do better grading. Changes advisable in the spitzkasten. Changes which would be made in the investigation if repeated.

On some Methods for the Extraction of Nickel and Cobalt from their Ores. Abstract by the author, John E. Hardman.

This paper is divided into five parts.

1. The object of the thesis, showing the increasing importance of nickel and cobalt ores, the scanty knowledge we have of the metallurgy of these elements, and giving a plan of the thesis.

2. A statement, or description, of methods actually in use for the extraction of these metals, so far as the methods are known, on account of the secrecy with which the processes are kept by the proprietors. The details of two methods, one in use at Klefoa in Sweden, and the other at Dillenburg in Germany, are given.

3. A narration of experiments undertaken in accordance with the object of the thesis. Six series of experiments are described in full, and the results tabulated.

4. General deductions from, and applications of the results given in 3.

5. A detailed account of results obtained from an investigation of (1) Fischer's, (2) Rose's, and (3) Fleischer's methods for the quantitative separation and determination of cobalt and nickel, together with some facts regarding the chemistry of the two elements which are not generally noted in text-books; and some analyses of ores used during the whole investigation.

On the Smelting of a Silver-lead Ore from Merrimac Mine. Abstract by the author, Henry D. Hibbard.

A lot of low grade ore weighing 4½ tons, from the Merrimac Mine of Newburyport, was washed by the machines at the In-

stitute, and, by this treatment a No. 1 Smelting ore containing lead and silver, and a No. 2 second grade ore which held a good deal of silver but very little lead, were obtained. This lot of No. 2 was worked by Messrs. Jenney and Wood. The subsequent working of the No. 1 lot forms the subject of this thesis.

The ore weighed 628 lbs. containing 254 lbs. of lead and 6.15 oz. of silver. Its composition is here given.

Silica	Si_2O	6.2
Iron	Fe	14.6
Alumina	Al_2O_3	.7
Lead	Pb	40.4
Silver	Ag	.067
Copper	Cu	.6
Zinc	Zn	.7
Magnesia	MgO	3.3
Sulphur	S	18.19

This ore was first roasted in lots of 46 lbs. each for four hours on a furnace with hearth $3' \times 3\frac{1}{2}'$. The loss of lead in fume was $20\frac{1}{2}$ lbs. or 8.07 per cent. of all the lead in the ore; the per cent. of sulphur was diminished from 18.9 per cent. to 5.28 per cent.

The ore was next agglomerated to get it into better condition to go into the blast furnace, this operation converts the fine ore into lumps and thereby lessens the loss of ore in dust when it is worked in the blast furnace. The loss of lead in fume during the agglomerating was 11 lbs., or 4.3 per cent. of all the lead.

The ore was next smelted in the blast furnace to make argentiferous pig lead. The mixture of ore and fluxes used in running the furnace was

Ore	40 lbs.
Tapcinder	13
Limestone	3
Siliceous Slimes	$1\frac{1}{2}$
	$57\frac{1}{2}$

This mixture was fed with one seventh its weight of coke during the whole run. The composition of the fluxes was

		Tapcinder.	Limestone.	Slimes.
Silica	SiO_2	14.55	.5	45.79
Iron oxide	FeO	70.89	.0	21.
Alumina	Al_2O_3	8.08	.0	8.95
Lime	CaO	2.38	56.	4.01
Lead	Pb	.0	.0	7.61
Magnesia	MgO	.0	.0	7.72

This smelt gave a slag of the following composition:

Silica	SiO_2	24.28
Iron oxide	FeO	52.20
Alumina	Al_2O_3	10.48
Lime	CaO	5.30
Lead	Pb	4.44
Magnesia	MgO	1.37

During this smelting 81⅞ lbs. of lead or 32.23 per cent. of all the lead was lost partly in fume, partly in drops in the slag and partly as silicate in the slag, the proportional amounts however, of these several losses were not obtained.

This lead was then melted and desilverized by pouring into it 1 per cent. of melted zinc which rises to the top and carries with it the silver and gold. This addition of zinc and the separation of argentiferous zinc scum has to be repeated several times as follows:

Before 1st addition of zinc the lead contained 64 oz. silver per ton 2000 lbs.
After " " " " rem'n'ng " 16 " " "
" " " " " " " 2.48 " "
" 3d " " " " " .22 " "

The zinc was now distilled off from this alloy of lead. Zinc and silver and an alloy of lead and silver were left which were separated on a cupel. The loss of lead during the desilverizing was 1⅞ lbs. or 73 per cent. of the whole lead in the ore and in cupelling 8½ lbs. of lead or 1.34 per cent. were lost.

To sum up the losses were as follows:

Lead lost in roasting . .	. 20½ lbs., or	8.07	per cent.
" " " agglomerating .	. 11 "	4.30	"
" " " smelting .	. 81¼ "	32.23	"
" " " zincing . .	. 1¾ "	.73	"
" " " cupelling, etc. .	. 3½ "	1.37	"
Total . . .	118¾ lbs., or	46.70	per cent.

Total amount of lead obtained was 135¼ lbs. or 53.30 per cent.
The record of the silver is as follows:

The ore contained 6.15 oz.

In roasting and smelting the loss was	1.38 oz., or	22.44	per cent.
" refining and zincing "	1.09 "	16.09	"
" cupelling "	.21 "	3.41	"
Total lost . .	2.68 oz., or	41.94	per cent.
Total amount of silver obtained .	3.47 "	58.06	"

The record of the gold:

The ore contained $4.50.

Lost in roasting and smelting . .	$ .42 or	9.33	per cent.
" refining, zincing, and cupelling	$1.28	28.4	"
Total lost . . .	$1.70	37.73	"
Total obtained . . .	$2.80	62.27	"

Report on the Working, for Silver and Gold, of a Middle Grade Product from Ore of the Merrimac Mine, Newburyport. Abstract by the author, Walter Jenney.

The object was, to so concentrate the ore as to make a second or middle grade product which should contain minerals whose specific gravity would not allow them to be saved in the "Smelting Ore" without greatly diluting it, but which were supposed to carry quite a quantity of silver. Several processes were to be tried with the intention of finding, if possible, a method by which it would be possible to work such a product profitably.

850 lbs. of ore from the mine, when so concentrated, gave 1272 lbs. of this middle product, which assayed for gold $9.23

per ton, and for silver $11.28 per ton. The finding of so much gold was something of a surprise and caused the methods to be altered somewhat so to extract that also. The product was made up of quartz 20.654 per cent., siderite 37.204 per cent., pyrite 20.377 per cent., galena 11.589 per cent., and smaller quantities of ispickel, chalcopyrite, blende and serpentine. It was roasted in a reverberatory furnace till all odor of SO_2 had ceased coming off, and then ground with salt (5 per cent.) and roasted again. Assays showed that in this first roasting, 88 per cent. of the gold, and 23 per cent. of the silver were lost. Experiments were made by Amalgamating this chlorinated ore in a Washoe Pan and by (II) chlorinating it with Cl gas, dissolving in brine, precipitating as sulphides, running down with lead and cupelling, with the results shown below.

Amalgamating.	Per cent. extracted form *roasted* ore . .	Au 17,	Ag 23.
Gas Chlorination I.	" " " " . .	" 41,	" 70
" II.	" " " " . .	" 82,	" 61.

It will be seen that the chlorination process (with Cl. gas) worked much the best, and it would give much better results if the leaching had been carried on farther.

Assays of the different products are given below: —

	Silver.	Gold.
Raw ore assayed	$11.28	$9.23
Roasted ore (before chlorination) . .	11.91	——
Chlorinated ore	11.06	7.23
Tailings from Amalgamation . . .	6.80	6.03
" " Gas chlo. I. . . .	1.70	4.82
" " " " II. . . .	1.70	3.61

The inference is that on a similar product which would be obtained from a richer ore (this being a very poor ore) this process might be made to pay, especially if made to work continuously as could easily be done.

Treatment of Vershire, Vt., Copper Ore. Abstract by the author, H. C. Southworth.

The thesis was divided according to the following outline:

1. The ore, with its ultimate analysis and minerals contained.

2. An account of the treatment of the ore, and a description of the processes used.

3. Deductions from my experience in working the ore, with the modifications of treatment suggested by that experience, and the comparison of the methods, with remarks upon them.

4. Tables relating to blast furnace runs, roasts, analyses, etc.

The result of the work upon the ore, as is stated in Part 2 of the thesis, was a black copper containing about 98 per cent. of copper.

This was accomplished by two roasts in the kiln, and smelting twice in the blast furnace, and then taking the second matte and running it down in black lead crucibles, after roasting as well as possible in the reverbertory furnace.

The most interesting comparison is that of the work of the kiln with the reverbertory furnace, upon the same ore. This is shown by the following table:

	Roasting in Kiln.	Reverberatory.	
Amount of ore roasted	865¾	1019¼	lbs.
" " fuel used	105¾ (coke)	739 (coal)	lbs.
" " labor	8	52	hrs.
" " sulphur lost	131	122	lbs.
Percentage " "	15.14	about 12.	

As the reverbertory furnace was used by Mr. Bartol, I am indebted to him for a part of the information concerning the above table.

In speaking of modifications of treatment, the view was expressed that, by sufficient roasting — which could be done in the kiln — the ore might be run down at once into as good a matte as was got by smelting twice.

In this way a good black copper would be got with only two furnace runs.

Investigation into the Working of the Institute Ore-concentrating Machines. Abstract by the author, Thomas F. Stimpson.

This subject was divided for study between Mr. Wm. C. Flint and myself. The ore to be experimented upon was a very poor quality argentiferous galena ore from the Merrimac Mine, Newbury, and was found by inspection to consist of the following minerals: — Galena, Chalcopyrite, Quartz, Pyrite, Siderite, Arsenopyrite, Zinc-blende, Tetrahedrite and traprock, associated with the greenish-white gangue composed essentially of Silicate of Alumina. It was broken, crushed, and sifted, by the machine in the Mining Laboratory of the Institute. Of the 8485 lbs. ready for concentration a sample was taken and subjected to chemical analysis, with the following results: —

Lead	5.23 per cent.
Sulphur	5.45 "
Iron	4.24 "
Ferrous Oxide	9.24 "
Copper	.32 "
Arsenic	.27 "
Alumina	8.50 "
Oxide of Manganese	1.21 "
Zinc	.15 "
Lime	1.16 "
Magnesia	1.39 "
Alkalies	1.95 "
Carbonic Acid	7.02 "
Silicic Acid	52.75 "
Water	.96 "
Determined	99.44 per cent.

From the above the mineral constituents were calculated as follows: —

Galena	6.04 per cent.
Siderite containing manganese	18.51 "
Pyrite	7.36 "
Chalcopyrite	.93 "
Arsenopyrite	.90 "
Zinc-blende	.46 "
Siliceous gangue	65.24 "
Total	99.44 per cent.

An assay for the precious metals gave: —

Silver	.020	per cent.; 5.88 oz. to the ton.
Gold	.00067	per cent.; 196 oz. to the ton.

The subject was treated more or less fully under six headings, viz: —

1. Description of the Ore and Machines.
2. Narration of Experiments. Final Products made.
3. Estimation of the Cost of Running the Machines. Value of the Final Products made.
4. Theory of Concentration.
5. Investigation of Results. Comparison with the Theory (not fully completed).
6. Conclusions.

1. The description of the machines was confined to the Cone, the Spitzkasten and the Jigger.

2. The time occupied in concentrating the ore was about 29¼ hours, extending over a period of five days. The object in view, meanwhile, was to make two workable products of ore: (1) One which was rich in lead — a smelting ore; (2) a product which should be poor in lead but carrying silver which was to be extracted either by chlorination or by amalgamation.

The following are the workable products made during the run.

	Weight lbs.	*Per cent. Lead.*	*Per cent. Silver.*
Smelting Ore	624½	38.03	.049
Middle Grade Ore	1823½	8.97	.031

3. The object of considering the cost of running the mill in the Laboratory was more especially to gain some idea of the cost of working similar ores on a larger and more practical scale. It is evident that, by increasing the capacity of the machine, the cost of concentrating an ore could be greatly diminished.

The principal data for this purpose are presented as follows:—

	Weight. lbs.	Value Lead.	Value Silver.
The Ore before treatment . .	8485	$26.65	$27.24
Smelting Ore produced . .	624½	$14.24	$4.86
Middle Grade Ore produced .	1823½	9.81	9.23
Waste	6037½	4.47	11.38
	8485	$28.52	$25.47
Unaccounted for: Lead, 32 lbs. at 6 cts.		— 1.89	
Silver, 1.61 oz. at $1.10			1.77
		$26.63	$27.24

Cost of working ore:

Interest on capital of $1800, including wear, per day	$ .50	
Wages of 2 men at $2.00	4.00	
" " 2 boys at .75	1.50	
Coal for generating steam	.75	
Oil for lubricating	.25	
Cost per day . . .	$7.00	
Total cost for five days .		$35.00

4. In ore-working there are usually two distinct processes: 1. *Sorting*, by which the ore is separated into groups whose particles have a like falling-velocity in water; 2. *Sizing*, by which the coarser grains are separated from the finer, and by which, if the ore had previously been sorted, a concentration takes place.

5. In investigating the results of the experiment the investigation extended to the work done by the Cone, Spitzkasten No. 1, and the Jigger, in order to inquire into the proficiency of these machines as "sorters" or "sizers" — as the case happened to be. The results depended upon the chemical analysis, and the physical examination of the different sizes of grains in each product to be investigated.

6. An examination of some of the products showed that the concentration of the ore, in respect to its silver, was rendered particularly difficult on account of the manner in which that metal was disseminated throughout the whole mass

of ore; and, on the other hand, the concentrations for lead would have been much richer but for the manner in which particles of quartz and siderite were disseminated through the galena giving to it thereby a lower specific gravity. It is thought that a further study of the data already obtained will show that the machines did their work as completely as possible, considering the peculiar physical condition of the ore and the manner in which the process of concentration was necessarily hastened.

Experimental Working, by Wet and Dry Methods, of a Low Grade Silver and Gold Ore, from Newbury, Mass. Abstract by the author, F. W. Wood.

Three principal divisions may be made of this thesis as follows:

1. Description of certain wet and dry processes for the extraction of silver.
2. Description of the ore experimented upon.
3. Description of the experiments conducted in the Metallurgical laboratory, with conclusions drawn from the results.

In Part 1st it is endeavored to give, in as compact form as possible, descriptions of the following named processes with the chemical reactions involved in each: — Washoe amalgamation, Augustin, Ziervogel, Von Patera, and a smelting process used at Freiberg.

It was originally intended to conduct the experiments upon an argentiferous zinc blende, but as this could not be obtained, a middle grade product, separated in the washing of 8¼ tons of low grade ore from the Merrimac mine at Newbury, was substituted.

Part 2d gives a scheme of the washing, showing the products making up the ore experimented upon, an analysis of the ore, with some of the methods of determination employed, a calculation of the mineral species, and the results of assays of the ore.

Part 3d is devoted entirely to the description of the experiments which were as follows: —

1. Trial roast and lixiviation to determine the possibility of extracting any of the silver in the above ore by a wet method.

2. The working of 100 lbs. of ore by Augustin's process.

3. Experiment upon 500 grms. to determine the possibility of applying Ziervogel's process.

4. The working of 100 lbs. of ore by Von Patera's process.

5. The smelting of 100 lbs. for matte and the subsequent treatment of one fourth of the matte, for silver and gold, in the dry way.

The following are the results of the different processes: —

	Obtained, per cent.		*Lost, per cent.*	
	Silver.	Gold.	Silver.	Gold.
Trial Roast . .	7.8		92.2	
Augustin's . .	23.7	14.3	76.3	85.6
Von Patera's .	24.7	18.6	75.3	81.4
Smelting . .	33.3	62.9	66.7	37.1

The *per centage lost* includes the silver and gold in the residues from the wet processes.

The loss in Augustin's process was increased by the breaking of a crucible while in the furnace.

In the dry process, the roasting of the matte obtained by the first smelting was carried so far that not enough sulphur for the formation of a matte in the second smelting remained, hence a considerable portion of lead, and with it the silver, went into the slag.

The conclusion drawn from the experiments is, that in order to economically extract the gold and silver, instead of attempting to work such a product alone, it should be smelted with an ore rich in lead.

DEPARTMENT OF ARCHITECTURE.

Design for a Steam Fire Engine House. Abstract by the author, J. William Beal.

It was the object in this thesis to present the subject, not merely from an architectural point of view with regard to design and execution of drawing alone (although these were given the most careful attention), but more particularly from a practical point of view adapting the *theoretical* to the practical requirements of the problem, according to one's best judgment. This course, although it may not present such pleasing results as may have been obtained by selecting some subject involving more architectural design, has nevertheless served to initiate the student into the routine of service in actual work which is of the greatest value. To accomplish this object, thorough examinations were made into the Fire Department of Boston and Cambridge; through the kindness of the officers the practical workings of each branch of the department were shown. The Engine Houses varying from one another, the advantages or disadvantages of each were ascertained. In accordance with the information thus obtained the design was worked out, all points of construction being treated exactly as though it was an actual case of building, in every case the theoretical calculations being compared with work already executed. These calculations embraced calculation of girders and timbers for floors, calculation of foundations and retaining walls, the distribution of strains in the roof trusses and the calculation of their dimensions, also the stability of arches and their effect on walls. The drawings comprised directions, plans and sections, with details and a perspective view of the building.

A Town Hall. Abstract by the author, Geo. W. Capen.

The subject of this thesis, "A Town Hall" was chosen for a variety of reasons, the principal of which were, that there is comparatively little architecture in our country towns, also that

it afforded a good field for architectural composition and design, and lastly a good opportunity for the calculation of strength and stability.

The building was to be built of rough stone and was designed to meet the wants of a town of from five to six thousand inhabitants. It contained on the lower floor, offices for the town clerk (which office was provided with a fire-proof vault), tax collector, selectmen and janitor, besides a large library room and a hall for small public gatherings.

The whole of the second floor was occupied by a large and spacious hall for large public gatherings, which was provided with two suits of dressing rooms, one for ladies and one for gentlemen.

The hall was to be covered by an open timbered roof, with a balcony in the rear, a large and commodious stage in front and a long narrow balcony on either side supported by brackets which form an architectural composition with the roof trusses.

The design is executed in the modern gothic style, and has for its principal exterior feature, a clock tower with a dial facing each of the cardinal points of the compass.

Of the drawings accompanying the thesis, there were a front elevation, a ground plan and a hall plan drawn to a quarter-inch scale — a side elevation, a longitudinal and transverse section and a gallery plan drawn to an eighth-inch scale, besides a perspective drawn to a quarter-inch scale.

A Design for a Steam Fire-Engine House. Abstract by the author, W. E. Chamberlin.

The conditions of the problem were assumed as follows: —

A flourishing suburban town requires a house for a steam fire-engine with its hose-carriage, and accommodations for six "permanent men." The house, which is to be of brick and stone, is to have a tower where the hose is hung to dry.

The principal story is for the most part taken up by the large room where the apparatus stands. In the rear the stalls are arranged, also an office and a workshop.

The second story contains six sleeping rooms as near as possible to the staircase which is in a single run. There is also a parlor, a room for the fire-alarm battery, a bath-room and a grain room.

In the cellar are found the hose-trough, the heating-apparatus, &c., &c.

The tower, which is usually put on the rear of the building, has in this case been put on the front. This position, while detracting nothing from the convenience within, gives an opportunity for making the building more pleasing without.

In order to be assured of the best arrangements for the planning of the problem several of the best houses in Boston and Cambridge were visited, and useful hints obtained.

The drawings accompanying the text consisted of plans of the first and 2d stories and cellar, the two principal elevations, a longitudinal section, a perspective and a few details on a larger scale.

For mathematical calculations the following were made:

1. Dimensions of floor timbers in engine-room, (assuming the weight of engine ready for a fire as 8000 lbs. The fact that two-thirds of this comes upon the hind wheels was considered.)
2. Truss 32 ft. long in partition in 2d story.
3. Parlor flooring timbers.
4. Roof truss (this was a primary truss of 32 ft. span, each slope being braced by a strut from the bottom of the vertical tie-rod.)
5. The brick arches on the front of the house.

Design for a Railroad Station. Abstract by the author, Pierce P. Furber.

In the design accommodation was afforded for waiting rooms for both ladies and gentlemen, baggage and lunch rooms, freight, telegraph and ticket offices, with the necessary halls, vestibules, and side rooms, in a two story building, 32 ×

44 feet, having a one story wing, 32 × 53 feet, the material used being red brick with brown stone trimmings and blue slate roofs.

The accompanying drawings consisted of two floor plans, a piling plan, two elevations, a section, and perspective, all drawn to a scale of one-eighth of an inch to a foot. Calculations were made as to the number of piles necessary to support the building in a loose sandy soil, and as to the stability of the arch over the main entrance.

A design was made for the roof trusses, the proper dimensions of the different members composing them being determined by the aid of "Greene's Graphical Analysis of Roof Trusses," a load of 12 pounds per square foot of snow, and a wind pressure of 26.5 pounds per square foot being taken into consideration. The strength of the floors was discussed, as was the construction of a trussed partition.

DEPARTMENT OF CHEMISTRY.

On an impurity found in Commercial Acetone. Abstract by the author, John Alden.

In repeating Baeyer's experiments on the formation of Phorone by passing dry chlorhydric acid gas into Acetone, a solid crystalline body was formed, a fact not mentioned by Baeyer, or by those who have since repeated his experiment. The purification and analysis of this body form the subject of the thesis.

From the analysis made the body was judged to have the formulæ $C_4H_{11}N_2O_2Cl$ as the following results show: —

Carbon	31.45	31.07
Hydrogen	7.80	7.12
Nitrogen	17.45	18 12
Chlorine	23.10	22.98
Oxygen	20.55	20.71
	100.00	100.00

Judging from the reactions the body evidently had an acid structure, and a double arindo-structure. As the body was first formed, both groups of NH_2 were evidently saturated with HCl, but on exposure to the air HCl was given off, till finally only one remained combined.

The formation of this nitrogenous body was evidently due to an impurity in the acetone. Certain tests and analyses led to the conclusion that it was acetonitrile. To verify this conclusion, some pure acetone and acetonitrile were made, and the mixture of the two saturated with HCl, when the same crystalline body was formed, having the same properties and constitution.

The acetone was probably prepared from the by-products of aniline manufacture by Béchamp's process, in which it occurs. This would account for the presence of acetonitrile.

The relations of Carbon to Iron and its determination by the Chlorine Process. Abstract by the author, Chas. S. Bachelder.

The subject is treated as follows:—

I. Relations of Carbon, Silicon and Manganese to Iron:—

In this section is considered the importance of knowledge of the above named ingredients of commercial iron, as seriously affecting its value for different purposes; also the form in which these elements are supposed to exist in the Iron.

II. Methods of determining total carbon and the Möhler Chlorine Process:— Under this head is discussed the various methods for determining carbon, more especially that known as the Chlorine Process.

III. Experiments with the Chlorine Process: — In this section the results of a number of analyses are given, the various defects in the process pointed out, and methods given for avoiding them as far as possible. The conclusion is reached that when properly carried out the Chlorine process affords results, which compare not only with themselves, but also with those given by what are considered to be accurate methods.

LOWELL DEPARTMENT OF INDUSTRIAL DESIGN FOR 1876–77.

President Runkle: —

Dear Sir: — At the close of my fifth year I have the honor of submitting to you the following report. Of the graduates, twenty-two are in situations, besides a number of others who have left the school before the completion of the course, to finish their apprenticeship in mills as they have received offers of places. In my last report, it was stated that designers for silk and woolen goods must understand weaving, and the art of putting a design on the loom, During the past year we have established such a course; and the looms now in possession of the department have been presented, one by the Lewiston Machine Co. of Lewiston, Me; one by the Bridesburg Manufacturing Co. of Philadelphia; one, an English loom, by Mr. Edward A. Brigham of Boston; and two by Mr. George Crompton of Worcester, one a twenty-harness and four-shuttle loom, and one an improved Jacquard pattern-loom, expressly designed and built for the department. Messrs. Mudge, Sawyer & Co. have also kindly furnished us with the needed cotton and woolen yarns.

The object of this department is not simply to teach weaving, but to give the student a general idea of the way in which all woven fabrics are made, and to teach him to dissect any sample of cloth, and to reproduce it upon the loom, as well as to exhibit his own designs in the woven fabric. The following is a general outline of the course, which is in the immediate charge of Mr. A. D. Blodgett.

The first five lessons are devoted to learning the names of the various parts of the loom, and the function of each, the

drawing in, and mending of, the warp-threads, the filling of the shuttle, the oiling, the starting and the stopping of the loom, and the weaving of a simple cloth with two or three harnesses and one shuttle.

The sixth lesson is devoted to putting the warp into the loom, hanging the harnesses, and setting the reed.

The seventh lesson teaches the running of a loom with eight to twelve harnesses and one or two shuttles.

The five following lessons are devoted to designing and weaving patterns upon an eight-harness loom running four shuttles.

The eight following exercises are upon designing, setting up, and weaving patterns upon a twenty-harness loom and four shuttles.

Two lessons upon drawing in warps from drawing drafts made by the student. The work done in these two lessons is put upon the loom and woven.

The next eight lessons are upon an improved Crompton-Jacquard loom, consisting of designing, setting up, drawing in, and weaving various patterns.

The following is a list of the pupils who are now in situations: —

James L. Folsom	Hartford Carpet Co.	
Alex. Johnson	Pacific Mills	Boston.
Carroll S. Faunce	" "	New York.
Sam'l Hudson	" "	Lawrence.
Everett Anthes	Manchester Print Co.	Boston.
Mary Jefferson	" "	"
Elizabeth Mendum	" "	"
Chas. H. Cowdrey	Oriental Print Co.	"
Wm. Schroeder	" "	"
Edwin Foster	" "	"
Addie S. Bartlett	" "	"
Caroline Egerton	" "	"
Caroline A. Stafford	" "	"
Minnie E. Ricker	Hamilton Print Co.	"
Harriet A. Parker	Roxbury Carpet Co.	

Howard G. Hinckley	Merrimac Print Co.	Boston.
S. R. Eaton	" "	"
Edgar Eames	" "	"
Chas. H. Underwood	" "	"
Henry Symmes	" "	"
Reuben Winslow	" "	"
Frank Hyde	" "	"
Chas. A. Washburn	Sanford's Carpet Mills	New York.
Eva M. Close	Forbes' Lithograph Co.	Boston.
Henry P. Mabille	American Print Co.	New York.
Annie D. Stimers	Sprague Print Co.	"
John H. Tarbell	Donnell Manufac. Co.	
Edward Williams	Lithographer	Boston.
Henry Morse	Carpet Mills	Maine.

Respectfully submitted,

CHARLES KASTNER, *Director.*

MEMBERS OF THE SOCIETY OF ARTS

OF THE

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,

MARCH 1, 1878.

HONORARY MEMBER.

* Prof. Daniel Treadwell, Cambridge, Mass.

LIFE MEMBERS.

Allen, Stephen M. . Boston.
Amory, William . . "
Atkinson, Edward . "

Baker, William E. . "
*Bancroft, E. P. . "
*Beebe, James M. . "
Bowditch, J. I. . . "
Bowditch, Mrs. J. I. "
Brimmer, Martin . "
Browne, C. Allen . "
Bullard, W. S. . . "

Colby, Gardner . . "
Cummings, John . . Woburn.

Dalton, Chas. H. . Boston.
Davenport, Henry . "
Dupee, James A. . "

*Edmands, J. Wiley. "
*Eldredge, E. H. . "
Emerson, George B. "
Endicott, Wm., Jr. . "

Fay, Joseph S. . . "
Fay, Mrs. Sarah S. . "
Forbes, John M. . . "
Forbes, Robert B. . "
Foster, John . . . "

Gaffield, Thomas . . "
*Gardner, G. A. . . "
Gardner, John L. . "
Gookin, Samuel H. . "
*Grant, Michael . . "
Greenleaf, R. C. . . "
Grover, Wm. O. . . "

Hemenway, Mrs. M. Boston.
Hoadley, J. C. . . Lawrence.
*Huntington, Ralph . Boston.

Johnson, Samuel. . "

Kidder, Henry P. . "
Kuhn, Geo. H. . . "

*Lawrence, James . "
Lee, Henry . . . "
*Lee, John C. . . . "
* Lee, Thomas . . "
Lee, Thomas J. "

Little, James L. . . "
Lowell, John A. . . "
Lyman, Geo. W. . "

Matthews, Nathan . "
*McGregor, James . "
Mudge, E. R. . . . "

Nichols, Lyman . . "
Norcross, Otis . . "

*Pierce, Carlos . . Canada.
Preston, Jonathan . Boston.
Pratt, Mrs. William . "
Pratt Miss . . . . "

Richardson, Geo. C. . "
*Richardson, J. B. . "
Rogers, Henry B. . "
Rogers, William B. . "
Ross, M. Denman . W. Roxbury.
Ross, Waldo O. . . "
Ruggles, S. P. . . Boston.

* Deceased.

*Savage, James	Boston.	Tobey, Edward S.	Boston.
Sayles Henry	"	*Turner, J. M.	"
Sayles, Mrs. Willard	"		
*Sears David	"	*Upton, George B.	"
Shaw, Mary S.	"		
*Skinner, Francis	"	Wales, Geo. W.	"
*Stetson, Joshua	"	Wales, T. B.	"
		Wales, Miss	"
Thayer, Nathaniel	"	*Whitney, Joseph	"
Thorndike, John H.	"	Wolcott, J. H.	"

ASSOCIATE MEMBERS.

Adams, James	Charlestown.	Eastman, Ambrose	"
Adams, Joseph H.	Boston.		
Amory, T. C.	"	Farmer, Moses G.	"
Anderson, Luther W.	Quincy.	Flint, Charles L.	"
Appleton, Thos. G.	Boston.	Foss, L. Bacon	"
Atkinson, Wm. P.	"	Francis, James B.	Lowell.
Austin, Edward	"	Fuller, H. Weld	Boston.
Batchelder, John M.	Cambridge.	Gardner, James B.	"
Beal, James H.	Boston.	Gibbens, Joseph M.	"
Bender, Richard W.	"	Grandgent, L. H.	"
Bigelow, A. O.	"	Guild, Chester	"
Bigelow, Jacob	"	Guild, Henry	"
Bishop, Chas. J.	"		
Bond, George W.	W. Roxbury.	Hall, Thomas	"
Bond, W. S.	"	Hammond, George W.	"
Bouvé, T. T.	Boston.	Haven, Franklin.	"
Bowditch, Wm. I.	Brookline.	Hayes, S. Dana	"
Browne, Causten	Boston.	Heard, John T.	"
		Henck, John B.	Brookline.
Cabot, Samuel	"	Henshaw, John A.	Cambridge.
Carpenter, Geo. O.	"	Hewins, Edmund H.	Boston.
Carruth, Charles	"	Holmes, O. W.	"
Clapp, Wm. W.	"	Homans, C. D.	"
Clinch, John M.	"	Hubbard, Charles T.	"
Cummings, Nath'l	"	Hyde, George B.	"
Curtis, Frederick	"	Hyde, Henry D.	"
Davis, Barnabas	"	Jackson, J. B. S.	"
Delano, Jos. C	New Bedford.	Jasper, Gustavus A.	"
Denny, Henry G.	Boston.	Jenks, Lewis E.	"
Dewson, F. A.	"		
Dix, John H.	Boston.	Kehew, John	"
Dresser, Jacob A.	"	Kneeland, Samuel	"

Lamson, Chas. D. . Boston.
Langley, H. P. . . "
Lanza, Gaetano . . "
Lawrence, A. A. . "
Lee, Francis L. . . "
Leuchars, R. B. . . "
Lewis, Charles W. . Charlestown.
Lewis, Wm. K. . . Boston.
Lincoln, F. W. . . "
Little, James L., Jr. "
Little, John M. . . "
Lothrop, Sam'l K. . "
Lowe, N. M. . . . "
Lowell, John . . . "
Lyman, Theodore . Brookline.

Mansfield, A. K. . Cambridge.
Markoe, G. F. H. . Boston.
Mason, Robert M. . "
May, F. W. G. . . Dorchester.
May, John J. . . . "
McMurtrie, Horace . Boston.
McPherson, W. J. . "
Merrill, N. F. . . Cambridgep't.
Montgomery, Hugh . Boston.
Moore, Alex. . . . "

Newell, John . . . "
Nichols, James R. . Haverhill.
Norton, Jacob . . Boston.

Ordway, John M. . W. Roxbury.

Page, W. H. . . . Boston.
Parsons, Wm. . . "
Paul, J. F. . . . "
Peabody, O. W. . . "
Perry, O. H. . . . "
Philbrick, Edward S. "
Philbrick, John D. . "
Pickering, E. C. . . "
Pickering, H. W. . "
Pope, Edward E. . "
Prang, Louis . . . "
Putnam, J. P. . . . "

Rice, Alexander H. . Boston.
Richards, R. H. . . "

Ritchie, E. S. . . . Brookline.
Robbins, James M. . Milton.
Robinson, J. R. . . Boston.
Rotch, Benj. S. . . "
Ruggles, John . . . "
Runkle, John D. . Brookline.
Russell, LeBaron . Boston.

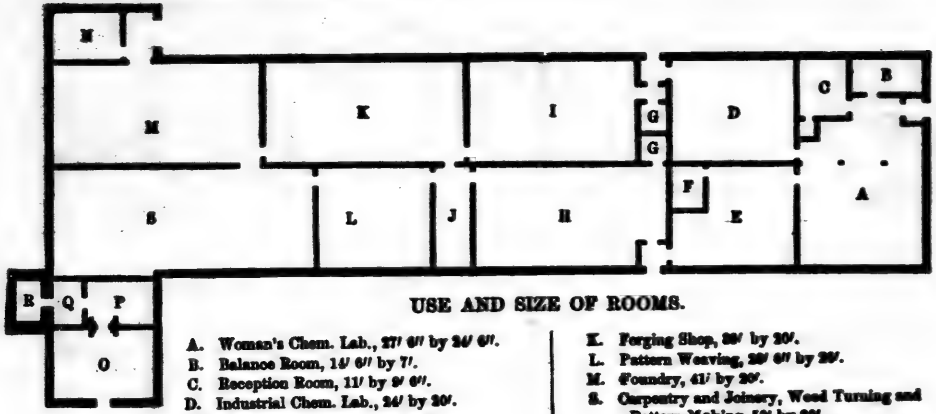
Salisbury, D. Waldo "
Sawyer, Edward . Newton.
Sawyer, Timothy T. Charlestown.
Sears, Philip H. . . Boston.
Sherwin, Thos. . . Dedham.
Shimmin, Chas. F. . Boston.
Shurtleff, A. M. . . "
Sinclair, Alex. D. . "
Smith, Chauncy . . Cambridge.
Sprague, Chas. J. . Boston.
Stevens, Benj. F. . "
Sturgis, John H. . "
Sullivan, Richard . "

Thompson, Wm. H. "
Tufts, John W. . . "

Upham, J. B. . . "
Urbino, S. R. . . . "

Ware, Chas. E. . . "
Ware, Wm. R. . . "
Warren, Cyrus M. . Brookline.
Warren, Geo. W. . Boston.
Warren, Joseph H. . "
Warren, Sam'l D. . "
Waters, C. H. . . . Clinton.
Watson, R. S. . . Milton.
Watson, Wm. . . Boston.
Weston, David M. . "
Whitaker, Channing "
Whitman, Herbert T. "
Whitmore, Wm. H. . "
Whiton, David . . "
Wilder, Marshall P. Dorchester.
Williams, H. W. . . Boston.
Winthrop, Robert C. "
Wright, John H. . . "
Wyman, Morrill . . Cambridge.

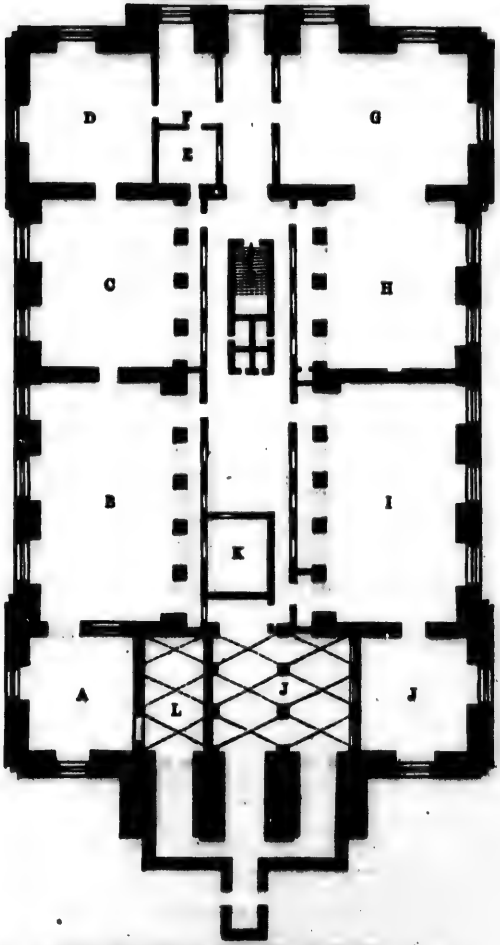
NEW TEMPORARY BUILDING FOR SHOP-WORK AND CHEMISTRY.



USE AND SIZE OF ROOMS.

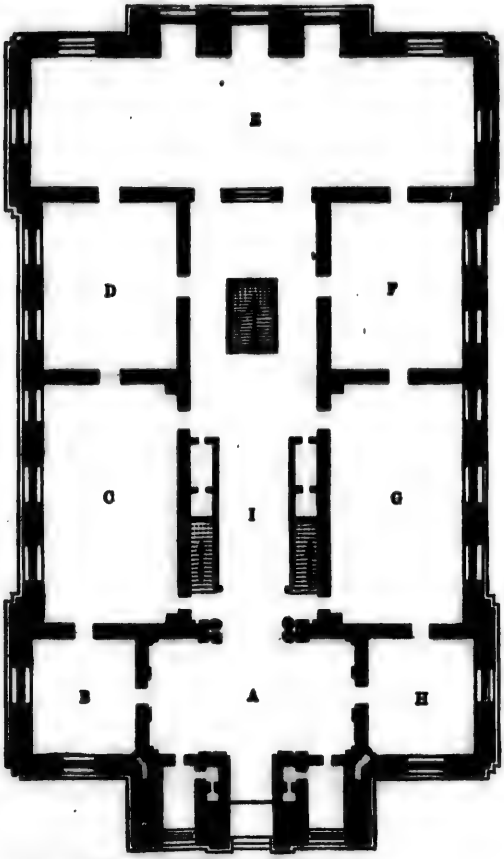
A. Woman's Chem. Lab., 27′ 6″ by 24′ 6″.
B. Balance Room, 14′ 6″ by 7′.
C. Reception Room, 11′ by 9′ 6″.
D. Industrial Chem. Lab., 24′ by 20′.
E. Microscopical Lab., 24′ by 20′.
F. Dark Room, Spectroscope.
G.G. Tool and Stock Rooms, 6′ by 6′.
H. Machine Tool Shop, 37′ by 20′.
I. Chipping and Filing Shop, 32′ 6″ by 20′.
J. Engine Room, 20′ by 7′ 9″.
K. Forging Shop, 20′ by 20′.
L. Pattern Weaving, 20′ 6″ by 20′.
M. Foundry, 41′ by 20′.
S. Carpentry and Joinery, Wood Turning and Pattern Making, 50′ by 20′.
N. Wax Room, 12′ 6″ by 9′ 6″
O. Organic Chem. Lab., 1′ by 14′.
P. Special Work Room, 12′ by 9′ 6″.
Q. Store Room, 9′ 6″ by 6′.
R. Ice Chamber, 8′ by 5′.

BASEMENT FLOOR.



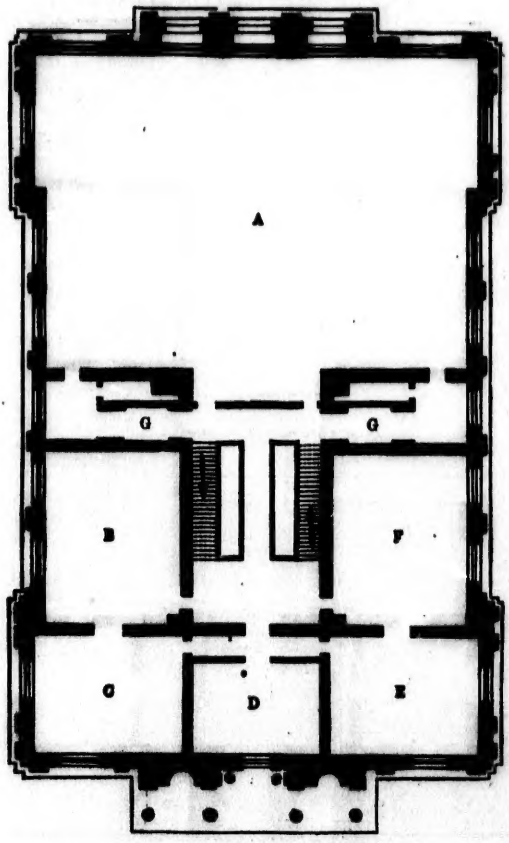
A. Professors' Chemical Laboratory, 25′ 0″ by 28′ 11″.
B. General and Qualitative Chemical Laboratory, 49′ 7″ by 24′ 0″.
C. Quantitative Chemical Laboratory, 25′ 0″ by 24′ 0″.
D. Quantitative Chemical Laboratory, 25′ 4″ by 24′ 0″.
E. Balance Room, 9′ by 12′.
F. Professor Wing's Private Laboratory, 16′ 0″ by 12′ 0″.
G. Mining Laboratory, 40′ 2″ by 27′ 10″.
H. Metallurgical Laboratory, 25′ 0″ by 24′ 0″.
I. Chemical Lecture Room, 49′ 7″ by 24′ 0″.
J. J. Mechanical Engineers' Laboratory, 25′ 0″ by 49′ 1″.
K. Daily Chemical Supply Room, 12′ 0″ by 12′ 0″.
L. Boiler Room, 12′ by 25′ 0″.

FIRST STORY FLOOR.



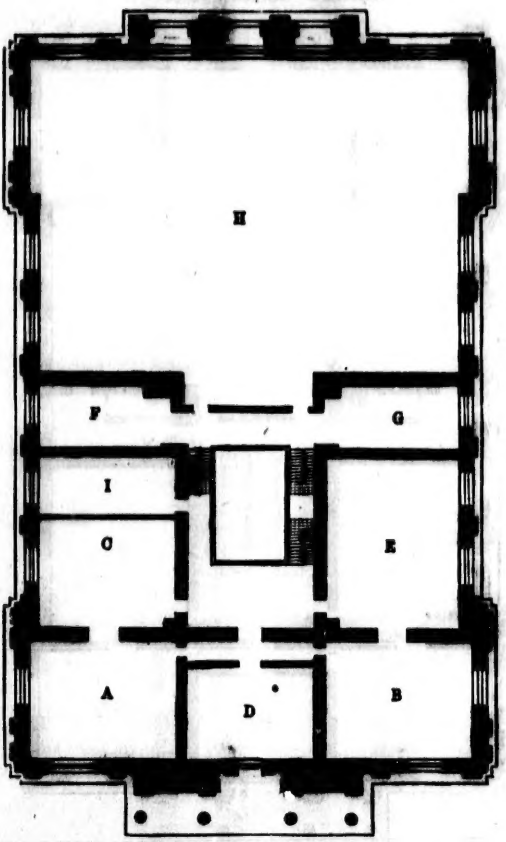
A. Entrance Hall, 49′ 9″ by 25′ 0″.
B. President's Office, 25′ 0″ by 22′ 11″.
C. Physical Lecture Room, 49′ 7″ by 28′ 9″.
D. Physical Laboratory and Apparatus Room, 25′ 9″ by 22′ 9″.
E. Physical Laboratory and Apparatus Room, 98′ 0″ by 27′ 10″.
F. Geological Lecture Room, 25′ 9″ by 22′ 9″.
G. Society of Arts Room, 49′ 7″ by 28′ 9″.
H. Secretary's Office, 25′ 0″ by 22′ 11″.
I. Stairway Hall, 27′ 9″ by 20′ 10″.

SECOND STORY FLOOR.



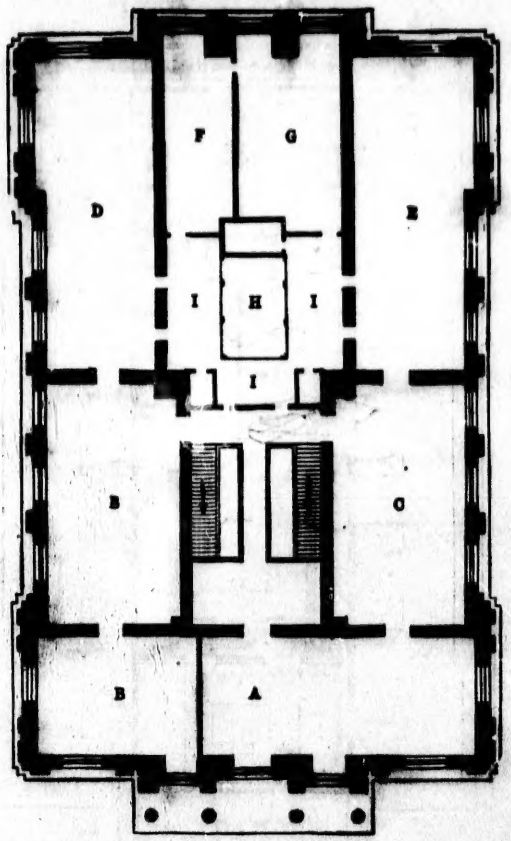
A. Huntington Hall, 62′ 0″ by 65′ 5″.
B. Mathematical Lecture Room, 24′ 9″ by 20′ 9″.
C. Civil Engineering Lecture Room, 22′ 2″ by 25′ 0″.
D. Modern Language Lecture Room, 22′ 2″ by 20′ 0″.
E. English Lecture Room, 22′ 2″ by 25′ 0″.
F. Mathematical and Astronomical Lecture Room, 24′ 9″ by 22′ 2″.
G. G. Passageways to Huntington Hall.

HALF STORY FLOOR.



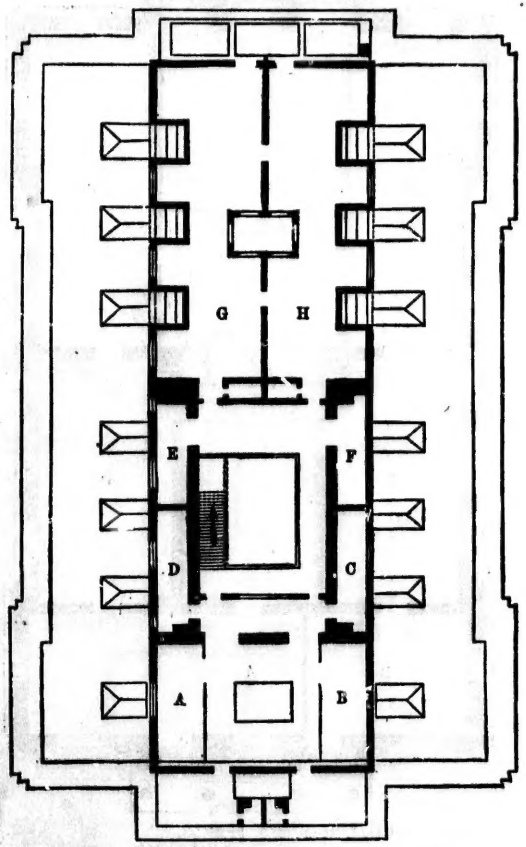
A. Architectural Museum, 28′ 2″ by 25′ 0″.
B. Architectural Library and Study Room, 28′ 2″ by 25′ 0″.
C. Architectural Museum, 28′ 2″ by 20′ 2″.
D. Natural History Lecture Room, 28′ 2″ by 20′ 6″.
E. Prof. Richards' Lecture Room, 34′ 0″ by 28′ 2″.
F. Prof. Atkinson's Study, 28′ 2″ by 14′ 2″.
G. Prof. Hunt's Study, 28′ 2″ by 14′ 2″.
H. Huntington Hall.
I. Prof. Howison's Study, 28′ 2″ by 14′.

THIRD STORY FLOOR.



A. Reading and Study Room, 62′ 0″ by 25′ 0″.
B. B. Civil Engineers' Drawing Rooms, 49′ 7″ by 23′ 3″.
C. First Year's Drawing Room, 49′ 7″ by 23′ 3″.
D. Mechanical Engineers' Drawing Room, 62′ 3″ by 23′ 0″.
E. First Year's Drawing Room, 62′ 3″ by 23′ 0″.
F. Mechanical Engineering Lecture Room, 27′ 0″ by 17′ 0″.
G. Mathematical and Descriptive Geometry Lecture Room, 27′ 0″ by 23′ 0″.
H. Model Room, 21′ 0″ by 13′ 0″.
I. I. I. Passage. way

FOURTH STORY FLOOR.



A. Prof. Lanza's and Prof. Whitaker's Study, 24′ 5″ by 11′ 6″.
B. Prof. Henck's Study, 24′ 5″ by 11′ 6″.
C. Prof. Osborne's Study, 24′ 9″ by 7′ 6″.
D. Prof. Richards's and Prof. Nichols's Study, 29′ 0″ by 7′ 9″.
E. Instructors Handy and Waitt's Study, 21′ 6″ by 7′ 6″.
F. Prof. Ware's Study, 24′ 9″ by 7′ 6″.
G. Architects' Drawing Room, 65′ 5″ by 21′ 10″.
H. Lowell School of Design, 65′ 5″ by 21′ 10″.